

National Management Measures to Control Nonpoint Source Pollution from Forestry

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The Nation's aquatic resources are among its most valuable assets. Although environmental protection programs in the United States have successfully improved water quality during the past 25 years, many challenges remain. Significant strides have been made in reducing the effects of discrete pollutant sources, such as factories and sewage treatment plants (called point sources). But aquatic ecosystems remain impaired, mostly because of complex problems caused by polluted runoff, known as nonpoint source pollution.

This guidance is designed to provide current information to state program managers on silvicultural nonpoint

Every two years the U.S. Environmental Protection Agency (EPA) reports to Congress on the status of the Nation's waters. The *1998 National Water Quality Inventory* (USEPA, 2000) reports that the most significant source of water quality impairment to rivers and streams and lakes, ponds, and reservoirs is agriculture, and the most significant source of impairment to estuaries is municipal point sources of pollution (Table 1-1). Other important sources of impairment include hydrologic modifications like dams and channelization (a leading source of impairment to rivers and streams and lakes, ponds, and reservoirs), urban runoff and storm sewers (a leading source of impairment to all surface waters), and pollutants deposited from the atmosphere (a leading source of impairment to estuaries). The most important types of pollutants impairing the Nation's waters are siltation, nutrients (from fertilizers and animal waste), bacteria, toxic metals, and organic enrichment that lowers dissolved oxygen. Siltation is the leading cause of water quality impairment to rivers and streams and the third leading cause of impairment to lakes, ponds, and reservoirs. Nine states list silviculture as a leading source of impairment to river and streams.

The Purpose and Scope of This Guidance

This guidance document is intended to provide technical assistance to state program managers and others on the best available, most economically achievable means of reducing the nonpoint source pollution of surface and ground waters that can result from forestry activities. The guidance provides background information about silvicultural nonpoint source pollution, including where it comes from and how it enters our waters. It discusses the broad concept of assessing and addressing water quality problems on a watershed level, and it presents up-to-date technical information about how to reduce silvicultural nonpoint source pollution.

Table 1-1. Leading Pollutants and Sources Causing Impairment in Assessed Rivers, Lakes, and Estuaries (USEPA, 2000).

| | Rivers & Streams^a | Lakes, Ponds, & Reservoirs^b | Estuaries^c |
|-------------------|---|---|---|
| Pollutants | Siltation | Nutrients | Pathogens (bacteria) |
| | Pathogens (bacteria) | Metals | Organic enrichment/ Low dissolved oxygen |
| | Nutrients | Siltation | Metals |
| Sources | Agriculture | Agriculture | Municipal Point Sources |
| | Hydromodification | Hydromodification | Urban runoff/ Storm sewers |
| | Urban runoff/ Storm sewers | Urban runoff/ Storm sewers | Atmospheric deposition |

^a Based on states' surveys of 23% of total river and stream miles

^b Based on states' surveys of 42% of total lake, reservoir, and pond acres

^c Based on states' surveys of 32% of total estuary square miles

The causes of silvicultural nonpoint source pollution, the specific pollutants of concern, and general approaches to reducing the effect of such pollutants on aquatic resources are discussed in the Overview (Section 2). Also included in Section 2 is a general discussion of best management practices (BMPs) and the use of combinations of individual practices (BMP systems) to protect surface and ground waters. Management measures for forest management and management practices that can be used to achieve the management measures are described in Section 3. Section 4 summarizes watershed planning principles and the application of management measures in a watershed context. Section 5 provides an overview of nonpoint source monitoring and tracking techniques.

Because this document is national in scope, it cannot address all practices or techniques specific to local or regional soils, climate, or forest types. Field research on management practices is ongoing in different parts of the country and under different harvesting circumstances to provide more guidance on how the practices mentioned in this guide and other management practices should be applied under specific circumstances.

Consult with state or local agencies, including the U.S. Department of Agriculture's Forest Service (USDA-FS), state forestry agencies, local cooperative extension services, and professional forestry organizations for additional information on silvicultural nonpoint source pollution controls applicable to your local area. Resources and Internet sites related to forestry are listed in Appendices A and B.

This document provides guidance to States, Territories, authorized Tribes, and the public regarding management measures that may be used to reduce nonpoint source pollution from forestry activities. This document refers to statutory and regulatory provisions which contain legally binding requirements. This document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose legally-binding requirements on EPA, States, Territories, authorized Tribes, or the public and

This guidance does NOT replace the 1993 *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal*

may not apply to a particular situation based upon the circumstances. EPA, State, Territory, and authorized Tribe decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. EPA may change this guidance in the future.

Readers should note that this guidance is entirely consistent with the *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (USEPA, 1993), published under section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). This guidance, however, does not supplant or replace the 1993 coastal management measures guidance for the purpose of implementing programs under section 6217.

Under CZARA, states that participate in the Coastal Zone Management Program under the Coastal Zone Management Act are required to develop coastal nonpoint pollution control programs that ensure the implementation of EPA's management measures in their coastal management area. The 1993 guidance continues to apply to that program.

This document modifies and expands upon supplementary technical information contained in the coastal management measures guidance both to reflect circumstances relevant to differing inland conditions and to provide current technical information. It does not set new or additional standards for section 6217 or Clean Water Act section 319 programs. It does, however, provide information that can be used by government agencies, private sector groups, and individuals to understand and apply measures and practices to address sources of nonpoint source pollution from forestry.

What Is Nonpoint Source Pollution?

Nonpoint source pollution usually results from precipitation, atmospheric deposition, land runoff, infiltration, drainage, seepage, or hydrologic modification. As runoff from rainfall or snowmelt moves, it picks up and carries natural pollutants and pollutants resulting from human activity, ultimately dumping them into rivers, lakes, wetlands, coastal waters, and ground water. Technically, the term *nonpoint source* is defined to mean any source of water pollution that does not meet the legal definition of *point source* in section 502(14) of the Clean Water Act of 1987:

Nonpoint sources, i.e., sources not defined by statute as point sources as described above, include return flow from irrigated agriculture, other agricultural and silvicultural runoff and infiltration, urban runoff from small or unsewered urban areas, flow from abandoned mines, and hydrologic modification.

The term *point source* means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged. This term does not include agricultural stormwater and return flows from irrigated agriculture.

Although diffuse runoff is typically treated as nonpoint source pollution, runoff that enters and is discharged from conveyances such as those described above is treated as a point source discharge and therefore is subject to the permit requirements of the Clean Water Act. In contrast, nonpoint sources, including runoff from silvicultural operations, are not subject to federal permit requirements. Point source discharges usually enter receiving waterbodies at some identifiable site and carry pollutants whose generation is controlled by some internal process or

activity, not by the weather. Point source discharges like municipal and industrial wastewaters, runoff or leachate from solid waste disposal sites, and storm sewer outfalls from large urban centers are regulated and permitted under the Clean Water Act.

Although water program managers understand and manage nonpoint sources in accordance with legal definitions and requirements, the nonlegal community often characterizes nonpoint sources in the following ways:

- Nonpoint source discharges enter surface and/or ground waters in a diffuse manner at irregular intervals related mostly to weather.
- The pollutants arise over an extensive land area and move overland before they reach surface waters or infiltrate into ground waters.
- The extent of nonpoint source pollution is related to uncontrollable climatic events and to geographic and geologic conditions and varies greatly from place to place and from year to year.
- Nonpoint sources are often more difficult or expensive to monitor at their point(s) of origin than point sources.
- Abatement of nonpoint sources is focused on land and runoff management practices, rather than on effluent treatment.
- Nonpoint source pollutants can be transported and deposited as airborne contaminants.

The nonpoint source pollutants that cause the greatest effects are sediments, nutrients, toxic compounds, organic matter, and pathogens. Hydrologic modification can also cause adverse effects on the biological and physical integrity of surface and ground waters.

Efforts to Control Nonpoint Source Pollution

During the first 15 years of the national program to abate and control water pollution (1972-1987), EPA and the states focused most of their water pollution control activities on traditional point sources. They regulated these point sources (and continue to regulate them) through the National Pollutant Discharge Elimination System (NPDES) permit program established by section 402 of the 1972 Federal Water Pollution Control Act (Clean Water Act). Under section 404 of the Clean Water Act, the U.S. Army Corps of Engineers and EPA also have regulated discharges of dredged and fill materials into wetlands.

As a result of the above activities, the United States has greatly reduced pollutant loads from point source discharges and has made considerable progress in restoring and maintaining water quality. However, the gains in controlling point sources have not solved all of our water quality problems. Studies and surveys conducted by EPA, other Federal agencies, and State water quality agencies indicate that most of the remaining water quality impairments in our rivers, streams, lakes, estuaries, coastal waters, and

wetlands result from nonpoint source pollution and other nontraditional sources, such as urban storm water discharges and overflows from combined sewers (sewers that carry both wastewater and storm water runoff). Summarized below are some legislative and programmatic efforts to control nonpoint source pollution from silvicultural activities. The examples focus on EPA's involvement in efforts to control nonpoint source pollution, and other Federal agencies, State agencies, and private organizations are also involved in nonpoint source pollution control efforts at local, state, and national levels.

Coastal Nonpoint Pollution Control Program

In November 1990, Congress enacted the Coastal Zone Act Reauthorization Amendments (CZARA). These amendments were intended to address several concerns, including the effect of nonpoint source pollution on coastal waters.

To more specifically address the effects of nonpoint source pollution on coastal water quality, Congress enacted section 6217, *Protecting Coastal Waters* (codified as 16 U.S.C. section 1455b). Section 6217 requires that each state with an approved Coastal Zone Management Program develop a Coastal Nonpoint Pollution Control Program and submit it to EPA and the National Oceanic and Atmospheric Administration (NOAA) for approval. The purpose of the program is "to develop and implement management measures for nonpoint source pollution to restore and protect coastal waters, working in close conjunction with other state and local authorities."

The Federal Coastal Nonpoint Pollution Control Program (6217) is designed to enhance state and local efforts to manage land use activities that degrade

Coastal Nonpoint Pollution Control Programs are not intended to replace existing coastal zone management programs and nonpoint source management programs. Rather, they are intended to serve as an update and expansion of existing programs and are to be coordinated closely with the coastal zone management programs that states and territories are already implementing in keeping with the Coastal Zone Management Act of 1972. The legislative history indicates that the central purpose of section 6217 is to strengthen the links between federal and state coastal zone management and water quality programs and to enhance state and local efforts to manage land use activities that degrade coastal waters and habitats.

Section 6217(g) of CZARA requires EPA to publish, in consultation with NOAA, the U.S. Fish and Wildlife Service, and other federal agencies, "guidance for specifying management measures for sources of nonpoint pollution in coastal waters." Section 6217(g)(5) defines management measures as

economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint source control practices, technologies, processes, siting criteria, operating methods, and other alternatives.

EPA published *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (USEPA, 1993). In that document, management measures for urban areas; agricultural sources; forestry; marinas and recreational boating; hydromodification (channelization and channel modification, dams, and streambank and

shoreline erosion); and wetlands, riparian areas, and vegetated treatment systems were defined and described. The management measures for controlling silvicultural nonpoint source pollution discussed in Section 3 of this document are based on those outlined by EPA in the coastal management measures guidance.

Nonpoint Source Program — Section 319 of the Clean Water Act

Section 319 requires states to assess non-point source pollution and implement management programs, and authorizes EPA to provide grants to assist state nonpoint source pollution control programs.

In 1987, in view of the progress achieved in controlling point sources and the growing national awareness of the increasingly dominant influence of nonpoint source pollution on water quality, Congress amended the Clean Water Act to focus greater national effort on nonpoint sources. Under this amended version, called the 1987 Water Quality Act, Congress revised section 101, “Declaration of Goals and Policy,” to add the following fundamental principle:

It is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this Act to be met through the control of both point and nonpoint sources of pollution.

More importantly, Congress enacted section 319 of the 1987 Water Quality Act, which established a national program to control nonpoint sources of water pollution. Under section 319, states, tribes, and territories address nonpoint source pollution by assessing the causes and sources of nonpoint source pollution and implementing management programs to control them. Section 319 authorizes EPA to issue grants to states, tribes, and territories to assist them in implementing management programs or portions of management programs that have been approved by EPA. In fiscal year 1999 and 2000, Congress appropriated \$200 million per year for this purpose.

National Estuary Program

EPA also administers the National Estuary Program under section 320 of the Clean Water Act. This program focuses on point source and nonpoint source pollution in geographically targeted, high-priority estuarine waters. In this program, EPA assists state, regional, and local governments in developing comprehensive conservation and management plans that recommend priority corrective actions to restore estuarine water quality, fish populations, and other designated uses of the waters.

Section 404 of the Clean Water Act

Section 404 of the Clean Water Act establishes a program to regulate the discharge of dredged and fill materials into waters of the United States, including wetlands. Activities regulated under this program include fills for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands to uplands for farming and forestry. The U.S. Army Corps of Engineers and EPA jointly administer the Section 404 program. The Corps administers the day-to-day program, including permit decisions and jurisdictional determinations; develops policy and guidance; and enforces Section 404 provisions. EPA develops and interprets environmental criteria used in evaluating permit

applications; determines the scope of geographic jurisdiction; and approves and oversees state assumption. EPA also identifies activities that are exempt, enforces Section 404 provisions, and has the authority to elevate and/or veto Corps permit decisions. In addition, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and state resource agencies have important advisory roles.

The basic premise of the program is that no discharge of dredged or fill material can be permitted if a practicable alternative exists that is less damaging to the aquatic environment or if the Nation's waters would be significantly degraded. In other words, an applicant for a permit is asked to show that

- Wetland effects have been avoided to the maximum extent practicable.
- Potential effects on wetlands have been minimized.
- Compensation has been provided for any remaining unavoidable effects through activities such as wetlands restoration and creation.

Regulated activities are controlled by a permit review process. An individual permit is required for potentially significant effects. However, for most discharges that will have only minimal adverse effects, the Army Corps of Engineers often grants general permits. These may be issued on a nationwide, regional, or state basis for particular categories of activities (for example, minor road crossings, utility line backfill and bedding) as a means to expedite the permitting process.

Section 404(f) exempts normal silvicultural activities that are part of an established, ongoing forestry operation. This exemption does not apply to activities that represent a new use of the wetland and that would result in a reduction in reach or impairment of flow or circulation of waters of the United States, including wetlands. In addition, Section 404(f) provides an exemption of discharges of dredged or fill material for the purpose of constructing or maintaining forest roads, where such roads are constructed or maintained in accordance with BMPs to assure that the flow and circulation patterns and chemical and biological characteristics of the navigable waters are not impaired, that the reach of the navigable waters is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized. (More information on wetlands and forestry, including a list of the aforementioned BMPs, is provided in section 3J.)

Total Maximum Daily Load (TMDL) — Clean Water Act Section 303

A total maximum daily load (TMDL) is a statement of the total quantity of a pollutant that can be released to a waterbody or stretch of stream or river on a daily basis to maintain the water quality standard for the pollutant. A single waterbody might have many TMDLs, one for each pollutant of concern. A TMDL is the sum of the individual wasteload allocations for point sources, load allocations for nonpoint sources and natural background sources, plus a margin of safety for an individual body of water. TMDLs can be expressed in terms of mass of pollutant per unit time, to aquatic organisms toxicity, or other appropriate measures that relate to state water quality standards.

The process of creating TMDLs was established by Clean Water Act section 303(d) to guide the application of state standards to protect the designated “beneficial uses” (e.g. fishing, swimming, drinking water, fish habitat, aesthetics) of individual waterbodies. Beginning in 1992, states, territories and authorized tribes were to submit lists of

impaired waters (i.e., waters that do not meet water quality standards) to EPA every two years. Beginning in 1994, lists were due to EPA on April 1 of even-numbered years. States, territories, and authorized tribes rank the listed waters by priority, taking into account the severity of the pollution and the waterbody's designated uses.

A TMDL is established to identify reduction targets for two types of water pollution sources in rivers and streams:

- Point source pollution
- Nonpoint source pollution

While point sources of water pollution are regulated by discharge permits, nonpoint sources are controlled by the installation of BMPs, either voluntarily or by regulatory requirement, depending on the state.

A TMDL is a process as well as an outcome. The following are components of TMDL development:

- Problem identification
- Identification of water quality indicators and target values
- Source assessment
- Linkage between water quality targets and sources
- Allocations
- Follow-up monitoring and evaluation plan
- Assembling the TMDL

Forest harvesting and road construction in forests can be sources of sediment and other pollutants to waterbodies. If a state determines that a priority waterbody is impaired by a pollutant that partially or wholly arises from forest harvesting or forest roads, the state will develop a TMDL for the waterbody and in it determine the maximum allowable quantity of the pollutant that can be released from harvest sites or forest roads. Some means of ensuring that no more than this quantity were released would then have to be implemented. BMPs are one method that could be used in conjunction with other methods chosen.

Forest Stewardship

Forest stewardship, including implementation of the management measures and BMPs in this guidance or similar ones (for instance, guides to state-recommended BMPs) to minimize water quality impairment due to forest harvesting and associated activities, is the responsibility of those who own and harvest the land. In the United States, timberland ownership is divided among public agencies, the commercial forest industry, and other private timberland owners. On a national scale, 73 percent of timberland is owned privately and 27 percent publicly. The distribution of ownership among different public and private entities differs widely by region, as summarized in Figure 1-1. Figure 1-2 shows the distribution of forested land throughout the country.

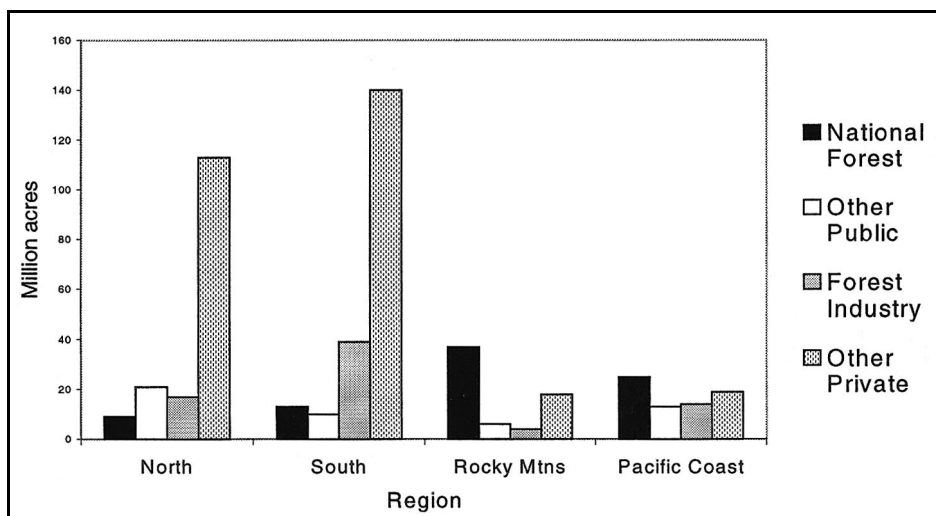


Figure 1-1. Timberland ownership by region (USFS, 1992).

This guidance is oriented toward the implementation of management measures and BMPs that will promote the protection of water quality, but it does not focus on assessing the quality of water that results from silvicultural activities. Other requirements, notably state water quality standards and designated uses, apply to all ownership categories and types of land-based activities. Thus, while different management measures and BMPs are recommended for silviculture and agriculture, for instance, maintaining state water quality standards is the responsibility of those who undertake both activities. It is the hope of EPA that the management measures and BMPs contained in this guidance, and the suggestions for their implementation, will help all persons involved with silvicultural activities and forest management to maintain the quality of waters in our forests nationwide.

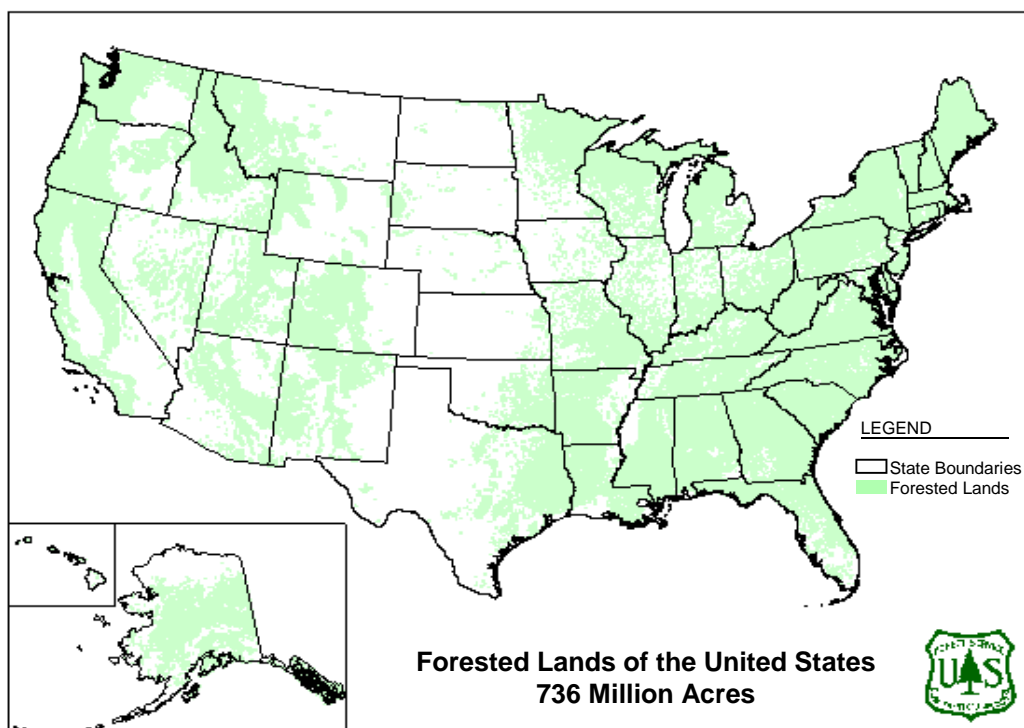


Figure 1-2. Forest Service and national parks land distribution.

Much surface water contamination in the United States is due to nonpoint sources of pollution. Chapter 1 defines and describes nonpoint source pollution. The primary silvicultural nonpoint source pollutants are sediment, nutrients, chemicals (herbicides, insecticides, and fungicides—collectively referred to as pesticides), organic debris, temperature, and streamflow. The effects of these pollutants are discussed below. Silvicultural activities can also directly affect the habitats of aquatic species through physical disturbances caused by the construction of stream crossings and equipment use within stream corridors.

The effects of forestry activities on surface waters is of concern to EPA and state and local authorities because of the value of healthy waters for aquatic life, drinking water, and recreational use. Surface waters and their ecology can be affected by inputs of nutrients, sediment, and chemicals and increases in flow that can result from forestry activities. Specifically, the purpose of implementing management measures and BMPs to protect surface waters during and after forestry activities is to protect important ecological conditions and characteristics of the surface waters in roaded and logged forested areas. These conditions vary with water body type, but generally, the ecological conditions that management measures are intended to protect include

- Water quality
- Shade along shorelines and streambanks
- The influx of carbon and nutrients that serve as the basis of aquatic food chains
- Inputs of large organic debris to which the aquatic system is adapted
- Streamflow patterns, both seasonal and annual

Although forestry activities can contribute nonpoint source pollutants to surface waters, a great deal has been learned in the recent past about effective ways to reduce such pollution. This Chapter introduces forested watershed hydrologic processes, the interaction of forestry activities with those processes, the general causes of silvicultural nonpoint source pollution, the specific pollutants and problems of concern related to forestry activities, general approaches to reducing the generation of those pollutants, and water quality problems associated with forestry activities.

Forested Watershed Hydrology

The following discussion summarizes key aspects of forest hydrology as provided in Reid (1993) and Ziemer and Lisle (1998).

A watershed is an area that, due to its natural drainage pattern, collects precipitation and deposits it into a particular body of water. In western regions of the country these land areas are often called "drainages," and throughout the Nation they're sometimes referred to as river or stream "basins" (CWP, 2000). Streamflow is a critical element in understanding watershed processes and the effects of land use on those processes because it is the primary medium through which water, sediment, nutrients, organic material, thermal energy, and aquatic species move. Streamflow is largely produced by ground water seepage. Ground water is supplied and replenished by rainfall and

snowmelt. The portion of water that infiltrates the soil percolates to the water table, then flows within the water table; is absorbed by vegetation, with a portion transpired back to the atmosphere; is adsorbed onto soil particles and later evaporated; or enters soil pipes (tunnels created by animals or decayed roots, etc.) and is delivered quickly to surface waters. Where soil loading by rainfall, snowmelt, or subsurface flow exceeds the soil's capacity, or soil cohesion is altered by weathering, and especially on steep slopes or in weak materials, landslides can occur.

Excess water, or that which cannot infiltrate the soil, runs off over the surface. Excess water is produced when water is delivered to a watershed surface faster than it can infiltrate the soil or when the soil is already saturated. Runoff volume, timing of production, and rate of transport through a channel system all affect both the rate of water delivery to any point in a channel network, and its ability to transport other watershed products (such as eroded soil and nutrients). Changes in any of these runoff characteristics affect downstream conditions.

There is little storage of water flowing over a forest floor, whereas subsurface storage in soil can be substantial. For this reason, water flows down hillslopes more than 10 times faster than it flows through soil. This factor contributes to increased peak flows in watersheds with substantial soil compaction or impervious surfaces. Loss of storage capacity in vegetation (that is, removal of a substantial amount of vegetation) can produce a similar effect. The extent to which water is prevented from infiltrating into soil and the amount of subsurface flow that is converted to overland flow are important factors that can affect the timing and volume of streamflow. Also, overland flow is much more likely than subsurface flow to cause erosion.

Stormflow response in small basins depends primarily on hillslope processes, while that in large basins depends primarily on the geomorphology of the stream channel network. Consequently, land use and other site factors have more effect in small basins and on smaller peak flows in large basins than on flows from major floods in large basins. In any watershed, however, streamflow response for a given rain event largely depends on the quantity of water intercepted prior to its reaching streams and the rate at which water reaches streams. A watershed with high water storage capacity in soil and vegetation can intercept more water, and streamflow response will tend to be spread out over time more than it would be if storage capacity were less and overland flow accounted for more water delivery to channels.

Streamflow during a season, the variability of streamflow within a season, and the variability of streamflow between seasons strongly influence channel form and processes. These factors also strongly affect aquatic and riparian species. In an equilibrated stream, each channel segment is precisely adjusted to carry off sediment contributed from upstream locations and from tributaries. Where the sediment input rate is greater than the energy in the stream to carry off sediment, sediment accumulates and a channel aggrades. Where a stream has more energy than what is necessary to carry the sediment the water is currently carrying, it can pick up extra sediment and incise the stream. The form of a watershed is modified by instream erosion or aggradation balancing the rates of sediment input from hillslopes against the rates of removal by runoff.

Forestry Activities and Forest Hydrology

When one factor in a system changes, other factors tend to become altered and compensate for the change, and both form and processes are likely to be modified in response. Logging has the effect of both compacting and loosening soils where heavy machinery is used on forest soils and logs are dragged over the surface, and removing a percentage of vegetation from a watershed. The main hydrologic problems caused by yarding and skidding are water channelling and flow diversion, which generate erosive flows. Roads and road building create areas of impervious soils and areas of loosened soils, can increase the amount of area that contributes to overland flow, can change subsurface flow to overland flow where subsurface flow is intercepted by road cuts, and can increase the network of surface channels that lead to streams via overland flow. These effects can increase overland flow and increase the amount of soil subject to erosion.

Tree removal tends to increase soil moisture and baseflow more in summer when evapotranspiration rates are higher and less in winter when the evapotranspiration rate is lower. This effect depends on local climate, of course, and the effect is more pronounced where seasonal differences are greater. Where the effect is noticeable, it usually disappears within several years after tree removal. Decreased evapotranspiration can increase average soil moisture, raise dry season water tables, and augment dry season baseflows. Stormflow peaks early and late in the wet season will tend to be more pronounced due to the limited storage volume in soils, but mid-season peaks are rarely affected. Stormflow peaks generally are affected more consistently by tree removal in areas where precipitation is distributed throughout the year.

Altered conditions caused by tree removal revert to precutting states at different rates. Shrubs and small trees regrow fairly quickly and water is evapotranspired from them. Larger trees take much longer to replace themselves, with consequently longer recovery periods from canopy effects, such as sunlight entry and rain and snow interception. Water yield from a watershed generally increases immediately after forest harvesting and returns to preharvesting levels within a few years.

The changes caused by roads can be very long-lived. Soil remains compacted and relatively impervious until vegetation reestablishes on it, roots begin to break it apart, and a litter layer and soil profile develop. Subsurface flow is continuously intercepted by road cuts, and regular maintenance such as cleaning culverts and repairing ditches and road drainage structures is necessary to prevent the failure of these structures. Without maintenance, roads will tend to deteriorate over time, become more susceptible to erosion, and contribute to sedimentation.

Hydrologic changes due to logging (resulting from tree removal and soil disturbance) and roads (resulting from soil compaction and imperviousness and increased channel connectivity) are more a function of the extent of the area logged and the length of roads in a watershed (that is, the quantity of each) and less a function of the harvesting method used or road building activity. Given an area of a watershed to harvest and a road network that must be in place or built to accomplish the harvest, the hydrologic changes that result are difficult to control. Soil erosion can be controlled more effectively than hydrologic changes by the choice of harvest location (and associated soil type and geology) and the methods used for road building, road maintenance, and timber removal.

Furthermore, road densities are often high in logged areas and the impacts associated with roads in logged areas tend to overshadow those from logging.

As stated previously, stormflow response in small basins depends primarily on hillslope processes, while that in large basins depends primarily on the geomorphology of the stream channel network. Hillslope processes are more influenced by forestry activities than is geomorphology. The effects of logging and roads, with compacted soils, areas of imperviousness, road surface runoff, interception of subsurface flows, and extensions of the channel network, are therefore proportionately larger in a smaller basin.

The types of forestry activities that can affect watersheds and water quality via nonpoint source pollution include road construction, maintenance, and use, and the universe of silvicultural operations, including timber harvesting, site preparation, and fertilizer and pesticide application. Some examples of these potential effects are taken from the scientific literature and provided in this chapter. Some of the studies cited here were conducted prior to the widespread adoption of forestry best management practices (BMPs), the implementation of logger education programs, and the creation of state programs for forestry BMP implementation and monitoring. These earlier studies provide a benchmark of the potential for road construction, timber harvesting, and other forestry activities to cause water quality effects when those potential effects are ignored or BMPs are not used to control erosion and sedimentation. Fortunately, many states have BMP programs, loggers are being trained in BMP use and forest ecology, and more research is being done on BMPs and the effects that forestry can have on watershed processes. The new research demonstrates where improvements can be made in protecting water quality and watersheds during forestry activities. The management measures and BMPs presented in Chapter 3 of this guidance are one part of an overall strategy to control the potential adverse effects of forestry activities on watersheds.

Road Construction and Use

Roads are considered to be the major source of sediment to water bodies from forested lands, and they can contribute up to 90 percent of the total sediment production from forestry operations (Megahan, 1980; Patric, 1976; Rothwell, 1983). Erosion is disproportionately high from roads because of their lack of vegetative cover, exposure to direct rainfall, tendency to channel water on their surfaces, and disturbed soils from their construction and use. Erosion from roads can be exacerbated by steep gradients on cut-and-fill slopes, subsurface water flow intercepted by a road surface and channelled over the road surface or through a ditch, overland flow from surrounding areas concentrated and channelled by a road surface, and lack of protective surfacing. Much of the sediment load associated with roads can be attributed to steep gradients, deep cut-and-fill sections, poor drainage, erodible soils, and stream crossings, and road-stream crossings are the most frequent source of erosion and sediment. Soil loss tends to be greatest during and immediately after road construction because of the unstabilized road prism and disturbance by passage of heavy trucks and equipment (Swift, 1984). See Chapter 3, sections 3C, *Road Construction/Reconstruction*, and section 3D, *Road Management*, for a discussion of means to reduce erosion from roads.

The association between forest roads and erosion has been studied for over 40 years. Dyrness (1967) observed the loss of 680 cubic yards of soil per acre from the H.J. Andrews Experimental Forest in Oregon due to soil erosion from roads on steep topography. Landslides were observed on all slopes and were most pronounced where

forest roads crossed stream channels on steep drainage headwalls. Figure 2-1 compares the incidence of mass erosion events from undisturbed forest, clearcuts, and roads in the Western Cascade Mountains in Oregon (Sidle, 1989). Note in the figure how mass erosion from roads is disproportionate to the amount of land area under use as roads. Brown and Krygier (1971) found that sediment production doubled after road construction on three small watersheds in the Oregon Coast Range. Another example of severe erosion resulting from forestry practices occurred in the South Fork of the Salmon River in Idaho in the winter of 1965, following 15 years of intensive logging and road construction. Heavy rains triggered a series of landslides that deposited sediment on spawning beds in the river channel, destroying salmon spawning grounds (Megahan, 1981).

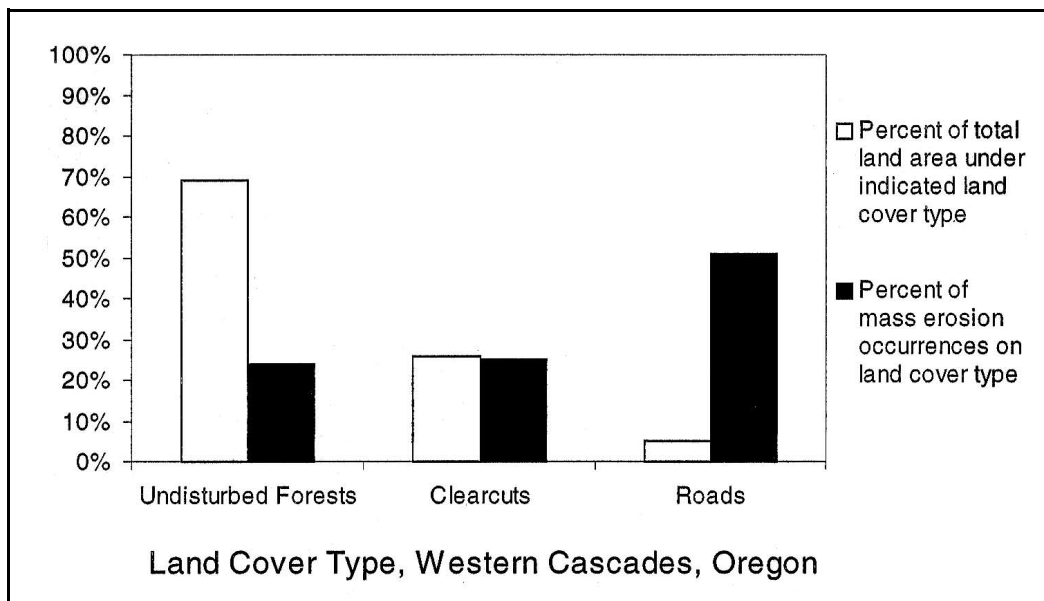


Figure 2-1. Comparison of forestland cover type and occurrences of mass erosion (adapted from Sidle, 1989). Note the low percentage of total area covered by roads and the large percentage of mass erosion events that occur on them.

Research on the effects of road/water connections has demonstrated the following general effects:

- Roads can disrupt the physical environment by changing surface runoff patterns, sedimentation, and soil characteristics such as soil density.
- Roads can alter the hydrology of slopes and stream channels.
- Roads can create barriers to the movement of fish and other aquatic animals.
- Roads can affect the chemical environment by contributing pollutants such as heavy metals, salts, and petroleum-based products to aquatic ecosystems through runoff.

Careful planning and proper road layout and design (see Chapter 3, section 3A, *Preharvest Planning*), however, can minimize erosion and substantially reduce the effects of roads on streams. The effect that a forest road network has on sediment input and flow changes in stream networks depends in part on how interconnected the road and stream networks are. Roads generally are hydrologically connected to stream networks where subsurface ground water flow is converted to channelled overland flow at road cuts, and road surface runoff drains directly to stream channels. Recall that overland

flow is delivered to streams much more quickly than subsurface flow, so the conversion of subsurface flow to overland flow and the connectivity of road networks to stream networks can have an effect on stormflow patterns in streams (Jones and Grant, 1996; Montgomery, 1994; Wemple et al., 1996). Soil type and permeability, topography, and vegetative cover type affect road/stream connectivity, and erosion and sedimentation are generally worse where soils are more erosive, topography is steeper, and vegetative cover is less. Careful road system planning, taking watershed processes, soil type, topography, and vegetative characteristics into account, and designing with natural drainage patterns to minimize hydrologic connections of the road network to streams and maximize opportunities for filtering surface drainage, can reduce these effects.

Timber Harvesting

Apart from the potential detrimental effects of forest roads, discussed above, timber harvesting generally involves the use of skid trails, along which felled trees are dragged, and yarding areas, where the timber is collected for transport away from the harvest site, and machinery associated with skidding and yarding. Skid trails and yarding areas are other areas associated with forestry activities that have the potential to contribute nonpoint source pollutants to surface waters. Soil disturbance, soil compaction, and vegetation removal are the changes that can occur due to these activities that can contribute to water quality problems. Disturbed soils are more easily eroded, compacted soils permit less water to infiltrate into the soil and contribute more to overland flow, skid trails can tend to channel overland flow, increasing its erosivity, and a lack of vegetative cover exposes the disturbed and compacted soils to the erosive effects of rainfall and overland flow. Methods for reducing these detrimental effects are discussed in Chapter 3, section 3E, *Timber Harvesting*.

Another potential adverse effect of timber harvesting is an increase in stream water temperature that can result if excessive amounts of streamside vegetation are removed. Small streams are affected most by a loss of shade. One reason that streamside buffer strips, or streamside management areas (SMAs) are maintained is to minimize or prevent stream temperature increases. Stream temperature maintenance is important for fish in all phases of their life cycles—egg, fry, juvenile, and adult. Stream temperature has been found to affect the time required for salmonid eggs to develop and hatch (Chamberlin et al., 1991). Adult spring chinook salmon have been found to prefer pools in cool streams undisturbed by logging, grazing, and agriculture to pools in streams where disturbance had occurred (Torgersen et al., 1999). Since all fish are cold-blooded, species and populations are adapted to particular ranges of water temperature and are biologically affected by temperature changes. Maintaining streamside vegetation in an amount sufficient to provide shade that regulates stream temperature is a key goal of the Streamside Management Area Management Measure (see Chapter 3, section 3B, *Streamside Management Areas*).

The removal of streamside vegetation can have another effect on stream ecology. Trees and branches overhanging streams and rivers contribute organic material in the form of leaves and needles, and large woody debris, or LWD, to surface waters. These materials fall into the water and serve as a source of energy in a stream's ecology and provide nutrients for aquatic life. They are a primary source of nutrients in small, low-order streams high in watersheds where aquatic vegetation might not be abundant and upstream sources of nutrients are limited. Farther downstream, instream sources of

nutrients, such as aquatic plants and organic matter transported from upstream sources, are more abundant and organic debris from overhanging trees is a less important source of energy and nutrients. LWD is still important in these streams, however, for the habitat diversity it creates. LWD creates eddies, provides shelter and anchoring points for small aquatic animals, and forms areas of relatively calm water in flowing streams and rivers. These areas are suitable for animals and plants that are less adapted to fast currents. Another reason that SMAs are managed as limited-use areas within harvest sites is to protect these important ecological processes and benefits.

Site Preparation and Forest Regeneration

Site preparation is done to prepare a harvested site for regeneration by seeding, planting, or from sprouts. It is accomplished mechanically using wheeled or tracked machinery, by the use of prescribed burning, or with applications of chemicals (herbicides, fertilizers, and pesticides). These techniques may be used alone or combined. Water quality can be affected by these operations due to erosion from soils disturbed during site preparation and from chemicals that are borne by overland or subsurface runoff to surface waters.

Mechanical site preparation by large tractors that shear, disk, drum-chop, or root-rake a site can result in considerable soil disturbance over large areas and can seriously deteriorate water quality (Beasley, 1979). Site preparation techniques can result in the removal of vegetation left after a harvest and forest litter, soil compaction and a loss of infiltration capacity, and soil exposure and disturbance. All of these effects can lead to increased erosion and sedimentation, and they are most pronounced soon after a harvest and decrease over time as vegetative cover returns to the harvested site. Means to reduce soil disturbance during site preparation

Forest regeneration methods can be divided into two general types: (1) regeneration from sprouts and seedlings, either planted seedlings or those present naturally on a harvest site, and (2) regeneration from seed, which can be natural seed in the soil or seed from a broadcast application after a harvest. In some areas, mechanical tree planting is conducted because it is fast and is consistent, and additional soil disturbance can result from the operation. Loss of soil from a harvest site is undesirable because of the lowered soil productivity and poorer regeneration that can result. Protecting a harvest site from undue disturbance during site preparation, therefore, is important both from water quality (reduced erosion) and site productivity perspectives. Means to protect soils from erosion and undue disturbance during site preparation and forest regeneration are discussed in Chapter 3, section 3F, *Site Preparation and Forest Regeneration*, and section 3H, *Revegetation of Disturbed Areas*.

Prescribed Burning

Prescribed burning is a method used to prepare a site for regeneration after a harvest, though because the methods for minimizing water quality effects due to fire are somewhat specialized, it is treated separately in this document (see Chapter 3, section 3G, *Fire Management*). Prescribed burning of slash can increase erosion by eliminating protective cover and altering soil properties (Megahan, 1980). The degree of erosion

following a prescribed burn depends on soil erodibility; slope; timing, volume, and intensity of precipitation after a burn; fire severity; cover remaining on the soil; and speed of revegetation. Erosion resulting from prescribed burning is generally less than that resulting from roads and skid trails and from site preparation techniques that cause severe soil disturbance (Golden et al., 1984). However, serious erosion can occur following a prescribed burn if the slash being burned is collected or piled and soil on the harvest site is disturbed in the process of preparing for the burn.

In general, wildfire has a more severe effect on watershed processes than prescribed burning because it is usually more intense than a prescribed burn, occurring when conditions for fire are more favorable. Prescribed burns are often set under conditions such that they can be controlled and the fire will burn lower and less intensely than would a wildfire. Burning can have the effect of making some soils water repellent, which will tend to increase runoff. This effect can penetrate to a depth of 6 inches and persist for 6 or more years after a fire. Burning enhances infiltration in other soils. Which soils will be affected in what way cannot be consistently predicted, and the effect is evidently dependent on the type of vegetation in the area burned (Reid, 1993; Ziemer and Lisle, 1998). Burning also releases nutrients, immediately increasing nitrogen available to plants, but will produce an overall effect of decreasing nitrogen in the forest floor (Reid, 1993).

The effects of fire on a watershed depend on burn severity and hydrologic events that follow a fire (Robichaud et al., 2000). Burn severity is related to the amount of vegetation loss and heat-related changes in soil chemistry due to a fire. The amount of vegetative cover in a watershed is probably the most significant factor in controlling runoff and erosion. On average, in watersheds with greater than 75 percent of the area in vegetative cover (both living plants and leaf litter), 2 percent or less of rainfall will become runoff, and rates of erosion are likely to be low. When fire reduces vegetative cover to less than 10 percent, runoff can increase to 70 percent of rainfall, and rates of erosion can increase by three orders of magnitude, especially where fire has a hydrophobic effect on the soil. Local conditions such as climate, slope, aspect, and tolerance of native vegetation to fire also help determine the short- and long-term hydrologic effects of fire.

Given the potential effects that a severe burn can have on watershed processes, prescribed burning, properly managed to reduce soil disturbance during preparation for the burn and to limit the severity of the burn, can be used effectively to reduce the chances of wildfire and the often more severe effects that the latter can have on watershed processes.

Forest Chemical Applications

Forest chemicals are another method that can be used to prepare a site for regeneration, as well as to protect forests from disease and pests. Adverse effects on water quality due to forest chemical applications typically result from not following the specific application directions for the chemical being used, which can lead to improper application, such as applying too much or not observing buffers around watercourses (Norris and Moore, 1971). Aerial application of forest chemicals has a greater potential to adversely affect water quality than ground-based applications, especially if chemicals are applied under unfavorable conditions, such as on windy days, or if they are applied directly to watercourses (Riekerk et al., 1989).

Precautions for minimizing water quality effects due to forest chemical use are discussed in Chapter 3, section 3I, *Forest Chemical Management*.

Forestry Pollutants and Water Quality Effects

The discussion above focused on forestry activities, the potential they have for generating nonpoint source pollution and pollutants, and the watershed processes that can be affected by forestry activities. Below is a discussion of the pollutants that can be generated from forestry activities and the potential effects that these pollutants can have on water quality.

The primary silvicultural nonpoint source pollutants are sediment, nutrients, chemicals (herbicides, insecticides, and fungicides—collectively referred to as pesticides), organic debris, temperature, and streamflow. Without adequate controls, forestry operations can cause sediment concentrations to increase because of accelerated erosion; nutrients in water to increase after their release from decaying organic matter on the ground or in the water, or after a prescribed burn; organic and inorganic chemical concentrations to increase because of harvesting and fertilizer and pesticide applications; slash and other organic debris to accumulate in waterbodies, which can lead to dissolved oxygen depletion; water temperatures to increase because of removal of riparian vegetation; and streamflow to increase because of increased overland flow, reduced evapotranspiration, and runoff channelling.

Size of watershed, soil type, topography, underlying geology, climate, season, type of vegetation, land use history, harvesting method, surface area compacted by machinery, surface area in roads, and the forest practices used to prevent erosion and runoff all play a role in determining how much, or how little, water quality is affected by silvicultural nonpoint source pollution. Figure 2-2 illustrates a model of forest biogeochemistry and hydrology. The discussions below of the individual pollutants that can be generated by forestry activities present the range of effects that might occur during and after road construction or use or a harvest. The particular effects of a forestry activities in a specific watershed will depend on the unique interaction of the characteristics of the area where the activities occur, time of year, harvesting method, and management measures used.

Sediment

Sediment is often the primary pollutant associated with forestry activities. Sediment is the solid material that is eroded from the land surface by water, ice, wind, or other processes and then transported or deposited away from its original location. Soil is lost from the forest floor by surface erosion or mass wasting (for example, landsliding).

Surface erosion generally contributes minor quantities of sediment to streams in undisturbed forests, and the quantity of surface erosion depends on factors mentioned previously, such as soil type, topography, and amount of vegetative cover (Spence et al., 1996).

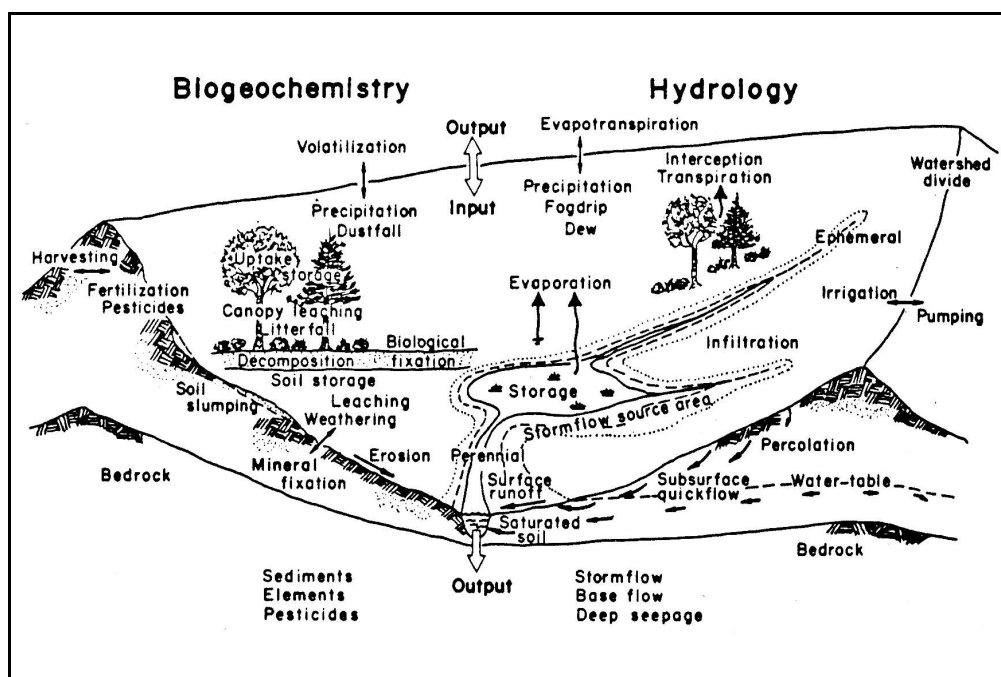


Figure 2-2. Conceptual model of biogeochemistry, hydrology, and stormflow source area interactions (Riekerk et al., 1989).

Channelized erosion and sheet erosion are the greatest contributors of surface sediments to streams. Channelized flow occurs where rainwater and snowmelt are concentrated by landforms, including berms on roads and roadside ditches. It causes the most severe erosion where the flow is permitted to travel for a long distance without interruption over steep slopes, which both tend to increase the volume and velocity of runoff. Sheet erosion, or overland flow, occurs most often on exposed soils.

Mass wasting, including slumps, earthflows, and landslides, occurs most often in mountainous regions where surface erosion is minor (Spence et al., 1996). It can produce large quantities of sediment in streams, but occurs episodically, usually following heavy rains, and in the western United States it is often associated with disturbed sites and steep slopes where vegetation has been removed, including where roads have been constructed, and the soil is not bound together by roots. Mass wasting and surface erosion that occur near streams have the most potential to affect in-stream conditions and aquatic communities.

An excessive quantity of sediment in a water body can cause or lead to a variety of problems. It can be detrimental to bottom-dwelling (benthic) organisms and fish because when it settles it can fill the spaces between rocks and grains of sand where many organisms live, forage, and spawn, hindering these activities. Fine sediments, of the size that can be deposited between grains of sand, are most threatening to fish. If deposited on fish eggs, it can reduce egg-to-fry survival and fry quality by suffocating eggs and forming a physical barrier to emerging larvae.

Coarser sediment can also cap a gravel streambed and restrict the emergence of alevins (Murphy and Miller, 1997). A study in British Columbia (Murphy and

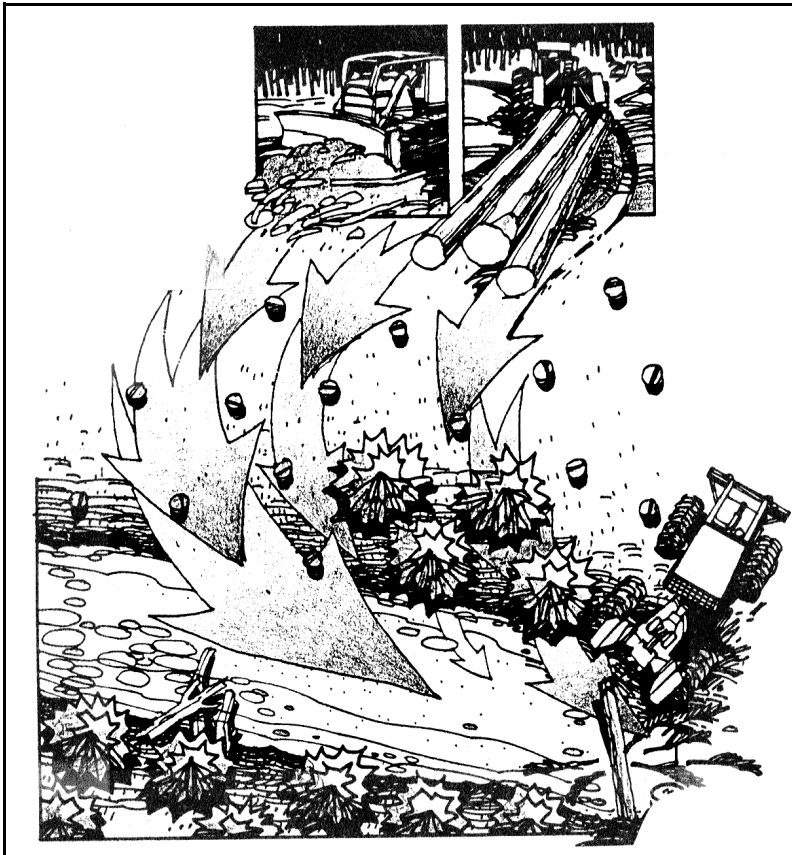


Figure 2-3. Vegetation removal and soil disturbance lead to soil loss and sedimentation in streams and other waterbodies (Montana State University, 1991).

Miller, 1997) found that fine sediment deposited in spawning gravels after timber harvest contributed to a 25 percent reduction in chum salmon escapement.

Sediment suspended in water increases turbidity, which limits the depth to which light can penetrate and can reduce photosynthesis and oxygen replenishment. Turbid waters are typically those with high concentrations of suspended sediment and/or organic matter. Taken into the gills of some fish, suspended sediment can cause the fish to suffocate, and it can severely limit the ability of sight-feeding fish to find and obtain food, especially if the turbidity is of long duration.

Sediment can be deposited to change the form of streams to make them wider and shallower and reduce their water-carrying capacity, and reduce the capacity

of reservoirs. Over time, the incidence of flooding might increase and water storage capacities might decrease.

Temperature

When streamside vegetation is removed, any increase in solar radiation reaching the stream can increase the water temperature. The temperature increase can be dramatic in smaller (lower order) streams and can heat the water to beyond the tolerance limits of some aquatic species. Increased water temperatures also accelerate the chemical processes that occur in the water and can decrease the ability of a waterbody to hold oxygen and lower the concentration of dissolved oxygen in the water.

Temperature increases in streams are of concern because of the potential effects on fish species. The water quality criterion of temperature is set in waters generally to protect fish species. Because streams in forests are shaded, fish species in forested streams are generally cold-water species such as salmon and trout. The duration of an elevated temperature and the availability of cool pools of water are among the factors that determine the severity of the effect that a temperature increase can have on fish. The effects that an elevated temperature can have on fish include retarded growth, reduced rearing densities, increased susceptibility to disease, decreased

ability to avoid predation, and decreased ability to compete with other species for food (Spence et al., 1996).

Leaving a riparian buffer (see Chapter 3, section 3B, *Streamside Management Areas*) is the primary means of minimizing temperature increase due to timber harvesting. The role of riparian buffers in regulating ambient stream temperature, however, varies with stream width and vegetation type, as well as other factors such as stream depth, orientation to the sun, and surrounding topography. Solar radiation reaching a small stream might be as little as 1 to 3 percent of the total radiation that would reach the stream if there were no tree cover, whereas it might be as much as 10 to 25 percent in a mid-order stream (Spence et al., 1996).

Streamflow

Streamflow is a concern because of the instream changes that can occur if the quantity of streamflow or the timing of streamflow is changed substantially as a result of a forest harvest or repeated forest harvesting. The dynamics of forest harvesting and streamflow response are discussed above under *Forested Watershed Hydrology*. Methods of minimizing the streamflow effects of forest roads and timber harvesting are discussed in Chapter 3, and particularly in sections 3C, *Road Construction/Reconstruction*, 3D, *Road Management*, and 3E, *Timber Harvesting*.

If forest roads or timber harvesting result in a more rapid delivery of runoff to streams than before roads were present or timber was harvested, then peak flows can be increased. This can lead to increases in channel scouring, streambank erosion, downstream sedimentation, and flooding. The magnitude of changes in peak flows after logging depends on the size of the watershed and the amount of land harvested, and to a lesser extent on road building. Changes are usually greatest in small watersheds where a large percentage of the surrounding watershed is logged at one time. Streamflow can be increased as a result of forest road building alone, but this usually occurs only in small, upland watersheds where streams and streamflow are small and the amount of impervious or heavily compacted surface from the harvest and associated activities is large in proportion to the areal extent of the watershed. Downstream flooding is rarely a consequence of logging in small, upstream watersheds (Adams and Ringer, 1994).

Normally, when only a small portion (e.g., less than 15 percent) of a watershed is harvested, flow is not altered in associated streams. Where more than 15 to 20 percent of the forest canopy is removed, streamflow typically increases. Any increase is greatest in the first years after harvest and typically becomes smaller with time as vegetation grows on harvested sites. Streamflow generally returns to the original level within 20 to 60 years, depending on forest and land type (Adams and Ringer, 1994).

Organic Debris

Organic debris is an important element of stream ecology because it serves as a source of energy and as an element of stream structure. It ranges in size from fallen trees to suspended organic matter in water. Naturally occurring large woody debris

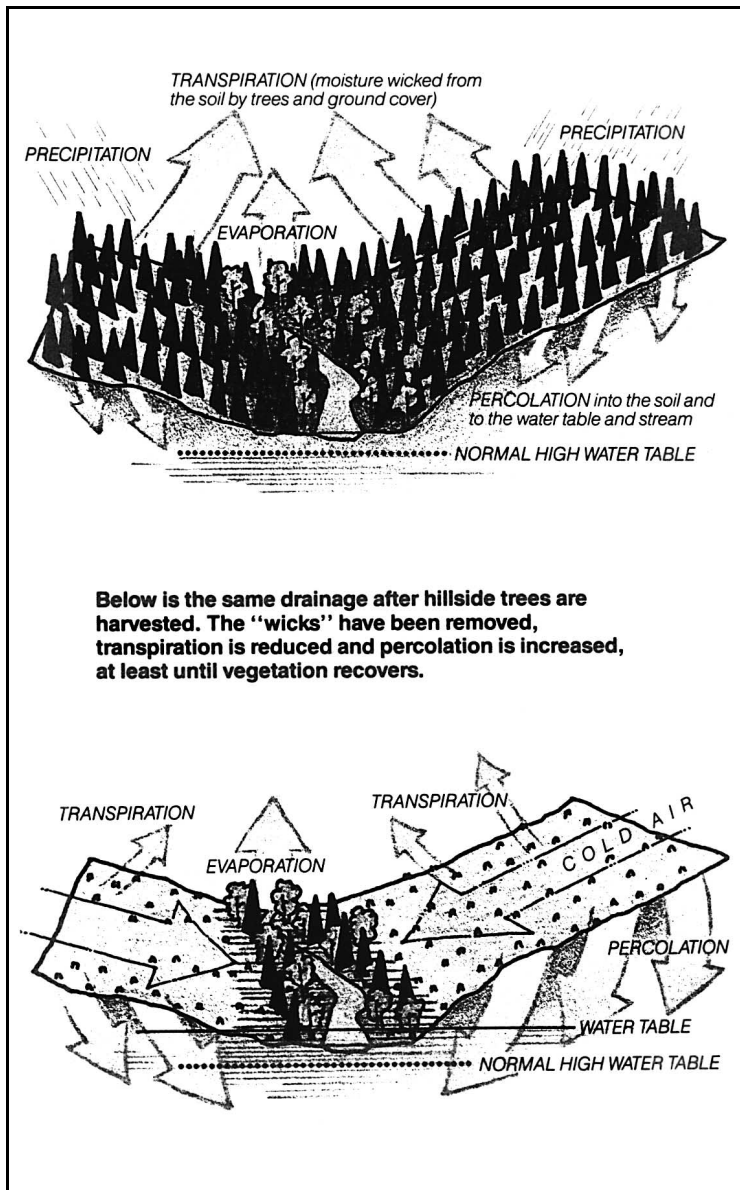


Figure 2-4. Streamflow and water table effects of forest harvesting (Montana State University, 1991).

(often simply referred to as 'LWD') enters streams as trees die or are undercut by streamflow. It falls into streams and creates the physical habitat diversity essential to maintaining biological diversity, rearing fish young, and providing refuge from predators. As a structural element, it influences the movement and storage of sediment and gravel in streams and stabilizes streambeds and banks (Spence et al., 1996). Smaller organic litter, primarily leaves in deciduous forests and cones and needles in coniferous forests, is an important food resource for aquatic communities that generally decomposes over a year or more, depending on forest type.

When streamside vegetation is removed, inputs of organic debris are decreased, and the amount of sunlight reaching the water is increased, a stream that might previously have relied primarily on outside sources of nutrients (falling debris) can be altered to one that relies primarily on instream sources, such as algal growth and instream vegetation. If this occurs, the food source available to fish and other aquatic organisms and local ecology is altered.

Organic debris generated during forestry activities can include residual logs, slash, litter, and soil organic matter. These materials can perform some of the same positive functions as

naturally occurring large woody debris and organic litter. If their abundance in a stream is substantially greater than normal, however, they can also block or redirect streamflow, hinder fish passage, alter nutrient balances, and decrease the concentration of dissolved oxygen as they decompose and consume oxygen.

Observing management guidelines for streamside management areas, discussed in Chapter 3, section 3B, *Streamside Management Areas*, is a key means to minimize ecological and water quality effects due to organic debris.

Nutrients

Nutrients, such as nitrogen and phosphorus, from fertilizers, soil, and plant material can enter waterbodies attached to sediments, dissolved in the water, or transported through the air. Sudden removal of large quantities of vegetation through harvesting

can increase leaching of nutrients from the soil into surface waters and ground waters. Excessive amounts of nutrients can enrich waterbodies, stimulating blooms of algae or overgrowths of aquatic vegetation. Either of these occurrences can increase turbidity (through the addition of excess decomposing plant material) and biological oxygen demand (again due to decomposing plant materials). Lowered levels of dissolved oxygen can result, with potentially detrimental effects to aquatic biota. Chapter 3, section 3I, *Forest Chemical Management*, discusses methods for minimizing the effects of forestry activities on nutrient balances.

Organic debris, discussed above, can serve as an important source of nutrients in an aquatic environment, so the management of streamside management areas can play an important role in maintaining nutrient balances in aquatic forest ecosystems.

Physical Barriers

Forest road stream crossings can be sites of hydrologic change, sedimentation, and debris buildup if the appropriate type and size of crossing are not selected. Improperly installed culverts at stream crossings, especially those installed above the grade of a stream, can create a barrier to upstream fish migration. Any of the following conditions associated with culverts can block fish passage: water velocity at the culvert is too fast, water depth at the culvert is too shallow, there is no resting pool below the culvert, the culvert is too high for a fish to jump, or the culvert is clogged because of lack of maintenance.

Problems associated with stream crossings can be avoided by proper planning (Wiest, 1998). Crossings can be located where they do not cause large increases in water velocity and there are not large changes in gradient or channel alignment. Doing so can minimize effects on sedimentation and fish passage. Planning for safe fish passage involves determining the type and extent of fish habitat, the species of fish present in the stream, and the window during which in-stream work can occur without harming fish habitat or interfering with fish migration. Safe fish passage is that which conserves the free movement of fish in and about streams, lakes, and rivers in order that they can complete critical phases of their life cycles. It permits adult fish to migrate to spawning areas and juvenile fish to accompany adult fish or make local moves to rearing or overwintering areas. The advantages and disadvantages of various stream crossing structures are summarized in Table 2-1.

Fords, bridges, and culverts of various sizes, shapes, and materials can be used to allow fish to pass safely and to avoid hydrologic and habitat changes. Management measures and BMPs for preventing physical barriers in streams associated with forestry activities are discussed in Chapter 3, sections 3C, *Road Construction/Reconstruction*, and 3D, *Road Management*.

Table 2-1. Advantages and Disadvantages of Stream Crossing Structures.

| Stream Crossing Structure | Advantages | Disadvantages | Notes |
|-----------------------------|--|--|--|
| Bridges | Best option for maintaining natural stream channel. Least effect on fish passage and habitat. | Expensive. Require special installation techniques. Difficult to fit to tight road curves. | No fish passage analysis is required. Require determination of 50- or 100-year flow. Should avoid in-stream piers. |
| Bottomless or Log Culverts | Unrestricted passage of fish. Preserve natural streambed and gradient. No significant change in water velocity. Maintain normal stream width. | Vulnerable to erosion and downcutting. Large logs might be required to achieve adequate flow with log culverts. Expensive and can be difficult to install. Not practical where footings cannot be placed in stable, nonerodible material. | Generally span the entire streambed and minimize effects on the natural stream channel. |
| Embedded Pipe Arch Culverts | When properly installed, maintain natural stream channel width, grade, sediment transport characteristics. | Complex and time-consuming installation. Sizing must account for area lost to embedding. Filling with machinery possible only if diameter large enough to permit machine entry. | Must be constructed on suitable bedding material. Suitable on bedrock when concert footings can be used. |
| Fords | Useful for low-water crossings. High-flow fish migration is unimpaired, low-water fish passage is easy to accommodate. | Can be barriers to fish passage during low-flow conditions. | Stream channel and slope must be suitable. Useful where transportation requirements are seasonal. |

Forest Chemicals

Herbicides, insecticides, and fungicides (collectively termed pesticides), used to control forest pests and undesirable plant species, can be toxic to aquatic organisms. Some pesticides are more readily transported to surface and ground waters than others. Some pesticides dissolve easily and can be extremely harmful, causing immediate or long-term effects, including reduced growth or reproduction, cancer, and organ malfunction or failure, in aquatic organisms. Persistent pesticides that tend to attach to sediment or debris in the water are also of environmental concern because they tend to bioaccumulate (accumulate in the tissues of living organisms).

Chapter 3, section 3I, *Forest Chemical Management*, discusses the management measure and BMPs for minimizing the addition of forest chemicals to surface waters during and after forestry activities.

Organic matter processing, geomorphology, streamflow, and temperature generally have longer recovery rates after harvesting disturbance.

Other harmful substances considered under the general category of “forest chemicals” and used during forestry operations include fuel, oil, and coolants used in equipment for harvesting and road-building operations. Improper use and management of any chemicals used during forestry operations can result in degraded water quality (Figure 2-5).

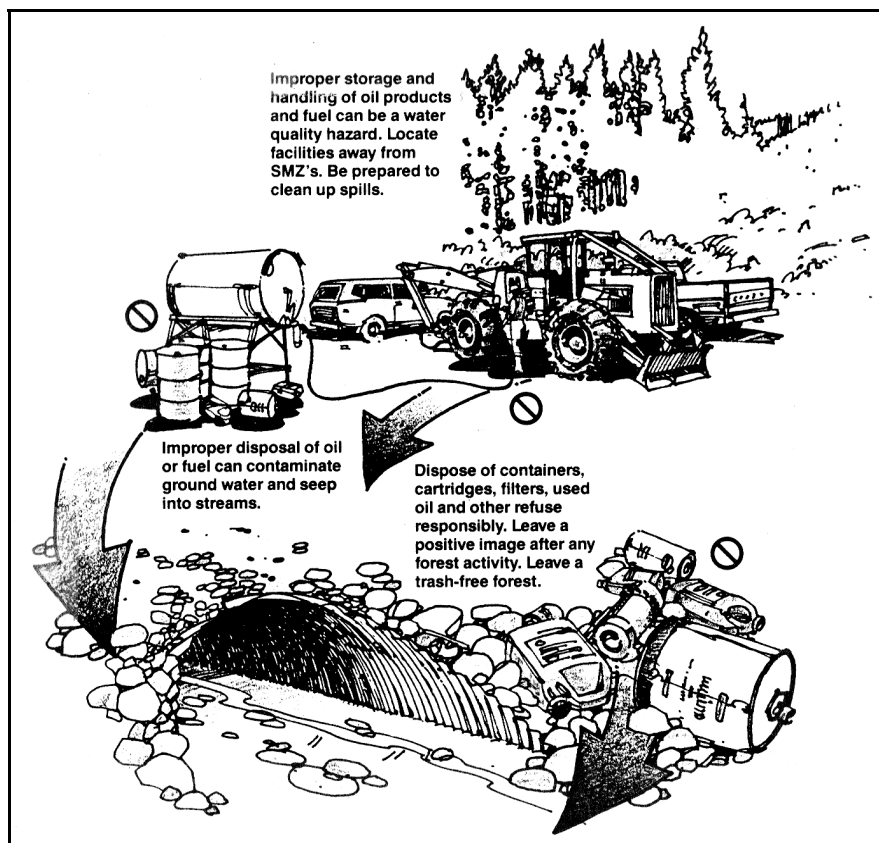


Figure 2-5. Improper storage or handling of forest chemicals can degrade water quality (Montana State University, 1991).

Cumulative Effects

Cumulative effects occur when two or more activities cause the same response within a watershed (e.g., lead to increased streamflow at a given time of year), when multiple responses disturb the same resource (e.g., increased streamflow and sediment yield both affect the same stream reach), when one response provokes another (e.g., increased streamflow induces scouring around culverts), or when responses interact to produce another (e.g., road construction on a steep slope and unusually heavy rains produce a mass soil movement) (Reid, 1993). Cumulative effects can occur spatially, when numerous activities conducted at different locations within a watershed contribute to instream responses, or temporally, when a single

activity repeated in the same place or different activities conducted in different places at different times have an additive effect. Most land use activities affect only one of four environmental parameters—vegetation, soils, topography, or chemicals—and other watershed changes result from initial effects on these factors. If a change in vegetation or another one of these four factors is persistent or affects watershed transport processes or rates, cumulative effects can result.

Cumulative effects are of concern with respect to forest roads; forest road construction, use, and maintenance; and forest harvesting because the changes that can occur in watershed processes following these activities can persist for many years. This persistence increases the potential for cumulative effects to occur. Examples of potential persistent effects due to forestry activities include the delivery of sediment to streams from a forest road used repeatedly over a period of years and increased subsurface flow and decreased evapotranspiration due to a reduced amount of vegetation at a harvest site.

It is important to note is that timber harvesting can cause changes to a stream's ecology on a temporal scale far different from that associated with the harvest. A harvest might occur in one season, or numerous harvests in a watershed might occur over a number of years, and during the months or years afterward temporary roads and stream crossings might be removed and the ground or streambeds rehabilitated. In contrast, full recovery to mature forest, in-stream recovery from channel erosion, habitat recovery, and aquatic community recovery might take up to 100 years or more.

Consider the following study of cumulative effects, modeled using Monte Carlo simulations of four hypothetical watersheds (Ziemer et al., 1991). Each watershed was a 10,000-ha, fifth-order watershed typical of one that might be located in coastal Oregon or California at 300 to 500 meters of elevation and 30 kilometers inland from the coast. Annual rainfall was simulated at 1500 millimeters. The four watersheds were simulated to have the following treatments:

- One watershed was simulated as undisturbed.
- One watershed was simulated as clearcut and roaded within 10 years of the commencement of harvesting, with harvesting beginning at the upper reaches of the watershed and progressing toward the mouth.
- One watershed was simulated as harvested at the rate of 1 percent per year, beginning at the mouth and progressing upstream.
- The fourth watershed was again simulated as harvested at a rate of 1 percent per year, but with the harvests widely dispersed throughout the watershed.

These harvesting patterns were simulated as being repeated each 100 years, and in each watershed (except the unharvested one) one-third of the road network was simulated to be rebuilt each 100 years. The greatest differences between the treatments were noticed in the first 100 years, and they related most to the rate of treatment. That is, to whether the harvests were concentrated or dispersed temporally. By the second 100 years, the primary difference between the treatments was in the timing of the impacts. Interestingly, the simulation indicated that dispersing the harvest units did not reduce cumulative effects.

Effects of Forest Harvesting on a Watershed Scale

A system of management practices designed for a specific logging operation can reduce the effects of timber harvest on soils, streams, and watershed ecology. This was clearly demonstrated by a study conducted in 3 small watersheds in Kentucky over a decade ago (Arthur et al., 1998).

In 1983 and 1984, 2 of 3 small watersheds were harvested. The third watershed remained uncut as a control. Management practices were used in one of the watersheds and no management practices were used in the other watershed. Both watersheds were completely clearcut. Soils in the watersheds were loamy and slopes averaged 45 percent.

The management practices used in the watershed with BMPs applied were those recommended by the state of Kentucky at the time and included streamside buffer strips 50 feet wide, minimization of road building effects by constructing them at minimum grade (<10%), use of water control structures on roads (broad-based dips), retirement of roads and skid trails after logging (all roads, skid trails and landings were seeded after the end of logging), and winching all logs to roads and then skidding them to landings.

During the first 17 months following the harvests, streamflow increased by 123 percent (relative to the control watershed) in the watershed with management practices and by 138 percent in the watershed where no management practices were used. Streamflows remained elevated for 8 years after the harvests.

During the harvesting period, suspended sediment fluxes were respectively 14 times higher on the watershed with management practices and 30 times higher in the watershed without management practices than in the control watershed. During the first 17 months after harvest, sediment flux averaged 4 times higher on the watershed with management practices and 6.5 times higher in the watershed without management practices than in the control watershed. The increased sediment fluxes were determined primarily to be due to a small number of discrete, high-sediment flow events, not to a continuous loss of sediment from disturbed sites. Sediment was also determined to have been lost from 3 major sources: streambank erosion, shallow landslides, and persistent erosion from roads. Overall, there was a much greater cumulative sediment flux from the watershed without management practices than from the watershed where management practices were used.

Clearcutting on both watersheds resulted in increased concentrations of nitrate and other nutrients (including potassium, calcium, sodium, and magnesium) in stream water compared to the control watershed. Nutrient concentrations were highest in the waters of the watershed where management practices were not used—they were 14.5 times higher than in the control watershed compared to 12.7 times higher in streams on the watershed where management practices were used. These concentrations declined after 3 years with the growth of secondary vegetation.

Clearly, clearcutting a large area can have effects on streams in the surrounding watershed. However, careful planning, design, and implementation of management practices can reduce the effects of harvesting to the land, water quality, and the organisms inhabiting streams.

Box 2A. Changes in streams after forest harvesting on a watershed scale (Arthur et al., 1998).

The conclusion reached by the authors was that current estimates of cumulative effects due to logging *underestimate* the effects because they accumulate over much longer periods than previously thought, but they *overestimate* the benefits of dispersing harvests in a watershed. Concentrating the treatments (over 10 years

instead of 100 years) increased the chances of cumulative effects on the affected resources.

A more detailed discussion of issues related to cumulative effect assessment is provided in Chapter 4, *Using Management Measures to Prevent and Solve Nonpoint Source Pollution Problems in Watersheds*.

Mechanisms to Control Silvicultural Nonpoint Source Pollution

Silvicultural nonpoint source pollution control practices are referred to as *best management practices* (BMPs), *management practices*, *accepted forestry practices*, *management measures*, *BMP systems*, *management practice systems*, and the like. Some of these terms have specific uses in legislation and regulations, whereas other terms are found in technical manuals, journal articles, and informational materials.

Most practitioners consider BMPs and management practices to be individual practices (such as streamside management areas) that serve specific functions (such as protecting streams from temperature increases due to increased sunlight and filtering sediment and nutrients from runoff from adjacent harvest sites). Management measures are groups of management practices used together in a system to achieve more comprehensive goals, such as minimizing sediment delivery to streams from harvest sites or soil disturbance during harvesting operations.

Management practices are the building blocks for management practice systems and management measures, and the implementation of the forestry management measures in this guidance, as appropriate, can result in comprehensive, technology-based water quality protection for most harvesting operations.

Management Measures

The management measures in this guidance contain technology-based performance expectations and, in many cases, specific actions to be taken to prevent or minimize nonpoint source pollution. Management measures are means to control the entry of pollutants into surface waters. Management measures achieve nonpoint source pollutant control goals through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods and other alternatives. Chapter 3 contains the recommended management measures for forestry.

For example, the management measure for site preparation and forest regeneration (see section 3F) contains the performance expectation *Confine on-site potential nonpoint source pollution and erosion resulting from site preparation and the regeneration of forest stands*. Statements of BMPs or actions that can be taken to achieve this performance expectation (e.g., *Conduct mechanical tree planting and ground-disturbing site preparation activities on the contour of sloping terrain*) are generally included in the management measure statement. Even so, in most cases there is considerable flexibility to determine how to best achieve the performance

expectations for the management measures. EPA's management measures for forestry and BMPs recommended to be used to achieve them are described in Chapter 3.

Best Management Practices (BMPs)

Criteria for determining what management practice is best for a particular location might include the amount of pollution prevention or pollutant removal anticipated, the ease of implementing the practice, how much maintenance it will require, its longevity, the willingness of landowners to implement the practice (in a program of voluntary implementation, for instance), and its cost and cost-effectiveness. The relative importance assigned to these and other criteria in judging what is best varies among states, within states, and among landowners, often for very good reasons. (For example, erosion control considerations are very different in mountainous western regions versus relatively flat southeastern coastal plain regions.) Additionally, choice of management practice is partially determined by the time-frame for their design, construction, and installation within the overall context of the associated forestry activities. With this in mind, and because of the common use of the acronym *BMP* when referring to management practices, this guidance uses the terms *management practice* and *BMP* interchangeably.

BMPs can be structural (e.g., culverts, broad-based dips, windrows) or managerial (e.g., preharvest planning, forest chemical management, fire management). Both types are used to control the delivery of nonpoint source pollutants to receiving waters in one of three ways:

- They minimize the quantity of pollutants released (pollution prevention).
- They retard the transport or delivery of pollutants, either by reducing the amount of water (and thus the amount of the pollutant) transported or by improving deposition of the pollutant (delivery reduction).
- They render the pollutant harmless or less harmful before or after it is delivered to a waterbody through chemical or biological transformation.

Management practices are usually designed to control a particular type of pollutant from specific land uses or activities. For example, stream crossings are specified and designed to control erosion from streambanks where roads cross them and sediment delivery from roads to streams. Management practices might also provide secondary benefits. Streamside management areas, for instance, reduce sediment delivery to streams and protect streams from temperature increases, and they also provide a source of large organic debris to streams and habitat for wildlife.

Sometimes, however, a management practice might increase the generation, transport, or delivery of a pollutant and is best used in combination with other management practices. Site preparation, for example, is generally performed for commercial timber regeneration and soil conservation, but can temporarily expose soil to erosive forces. Therefore, soil erosion control BMPs, such as establishment of a fast-growing ground cover to control soil erosion during the first years of tree regrowth, are recommended to be combined with low-effect site preparation techniques.

Management practices that can be used to achieve each of the forestry management measures are described in Chapter 3.

Best Management Practice Systems

Water quality effects cannot usually be controlled with a single management practice because forest harvesting involves many different activities at many different locations (e.g., road construction, timber transport on forest roads, harvesting at harvest sites, log skidding, and truck loading at yarding areas) and single practices cannot address the full range and extent of control needed at all of these sites. Both structural and managerial management practices are best used in combination as management practice systems to address treatment needs associated with pollutant generation from one or more sources. Management practices within a management practice system are usually more effective for controlling pollutants from single

causes since individual BMPs can be used at two or more points in the pollutant delivery process (Box 2B). For example, the objective of many forest harvesting nonpoint source pollution prevention efforts is to reduce the delivery of soil from forest harvest sites to waterbodies. A system of management practices can be designed to reduce erosion from forest harvest sites and associated roads and prevent sediment delivery to streams. Such a system could include waterbars and broad-based dips on forest roads, mulching and/or grass seeding beside roads, revegetation of harvest sites after the harvest, and a streamside management area along a stream to filter runoff from the forest harvest site and yarding area. Other management practices could be used as appropriate depending on the characteristics of the particular site. The effectiveness of these and other management practices is greatly influenced by the timing of installation (preferably early in the process) and their being regularly maintained, in addition to their being correctly designed and constructed.

Each structural and managerial practice used as part of a management practice system can be selected, designed, implemented, and maintained in accordance with site-specific considerations (e.g., slope, soil type, proximity to streams, and layout of the harvest) so it works effectively with the other management practices that form the system. This improves the ability of the practices to function together to achieve the overall

Effectiveness of a Management Practice System with a Site-Specific Design

A paired watershed study was conducted in two small watersheds to identify the “unavoidable” effects of forest logging on physical and chemical water quality. This required strict use of management practices and a road layout that included no roads crossing runoff-producing areas. One of the small watersheds was a control and the other, with an old-growth *Eucalyptus regnans* forest, was clearcut, burnt, and replanted. Each of the watersheds had deep, permeable soils.

The management practices employed on the clearcut watershed included a suspension of logging during wet weather, streamside buffer strips with a minimum width of 20 m, drainage of all runoff from trails and landing areas to areas of high soil infiltration capacity, expeditious replanting of all logged surfaces, and deep ripping of all compacted areas like landings. Additionally, a supervisor was always present to manage and inspect operations.

Employment of these management practices and strict management of operations resulted in the harvesting and regeneration operation not having any major effects on stream physical or chemical water quality. No effects were noted on stormflow.

This study demonstrates that it is possible to prevent contaminated runoff from reaching streams if areas that produce runoff are first identified, management practices are carefully chosen and applied, and the watershed is relatively insensitive to perturbation (e.g., has deep, permeable soils).

Box 2B. Implementation of management practice systems for pollutant control (Grayson et al., 1993).

management goals. For example, a streamside management area (SMA) is made wide enough to handle the volume of water and sediment expected to be delivered to it, taking into consideration the surrounding slope and proximity of roads and yarding areas and the type of litter layer. Roads, in turn, are designed or located to reduce the quantity of runoff delivered to the SMA, or management practices are added that “pretreat” the runoff to remove sediment before it reaches the SMA. Design standards and specifications that are compatible help ensure that practices will work together as an effective system.

Management Measure Effectiveness

States have used a number of approaches for assessing the effectiveness of management measures and BMPs. Florida and South Carolina have assessed their effectiveness using bioassessment techniques and stream habitat assessment. Florida has compared sites adjacent to harvests with unlogged reference sites, while South Carolina has compared sites upstream from harvests to those downstream from harvests and conditions at the same site before harvests to those after harvests. Maine and Virginia have placed in-stream water quality samplers in streams near forest harvest operations. South Carolina and Washington have used a weight-of-evidence approach, in which a variety of different assessment approaches are used and the conclusion about effectiveness arrived at most by the different approaches is accepted as the overall conclusion. South Carolina has concluded from its weight-of-evidence assessments that on sites with perennial streams, BMP compliance checks, stream habitat assessment, and benthic macroinvertebrate assessments can be used effectively to assess BMP effectiveness. The state has also concluded that on sites affected by other land uses, BMP compliance monitoring alone is reliable for assessing BMP effectiveness.

All of the approaches have produced valuable information about BMP effectiveness. The conclusions from these studies are many:

- BMP assessment monitoring is important for determining that the standards for design and implementation of BMPs are appropriate for the soils and topography where they are to be used.
- One or more BMP assessment approaches, including BMP compliance and an in-stream habitat or macroinvertebrate approach, can help determine that BMP implementation standards are adequate.
- Once it has been determined that implementation standards are appropriate, rigorous BMP compliance checks to verify that BMPs are being installed properly and in a timely manner and are being maintained adequately generally suffice as an indicator of BMP effectiveness.
- It is important to assess the effectiveness of BMPs under a variety of site conditions and to tailor implementation standards to different types of soils, slopes, and regional site characteristics if the BMPs are to be effective when applied.

- Proper application of BMPs during forest harvesting provides adequate protection of adjacent streams. BMPs adequately protect stream ecology and stream temperature, and they prevent sedimentation.
- When BMPs are not properly applied, they do not adequately protect water quality. Improperly applied BMPs can result in stream sedimentation, changes in stream morphology, higher average water temperatures, wider water temperature fluctuations, and shifts in stream ecology.
- Many water quality problems that arise from forest harvesting are associated with improperly applied or missing BMPs. The most frequently misapplied or missing BMPs are those for road surface drainage control, erosion control prior to the harvest, stream crossings, and SMAs.
- States are not adequately addressing some water quality problems associated with forest harvesting. BMPs for ephemeral streams are lacking and are not applied rigorously to protect such streams, which can produce or deliver large quantities of sediment to other streams. BMPs for the protection of unstable slopes need improvement.
- The most important BMPs for protecting stream water quality are properly sized SMAs, properly designed BMPs for erosion control implemented prior to the commencement of road construction and harvesting, properly sized and implemented stream crossings, and comprehensive preharvest plans.

Examples

Examples of how management practices can operate as a system to control nonpoint source pollution are given in a paper that summarizes a national effort by USDA's Forest Service to develop analysis procedures for estimating the economic benefits of soil and water resource management (Dissmeyer and Foster, 1990). The paper focuses on benefits in five areas—timber, forage, fish, enhanced water quality, and road construction and maintenance. The benefits noted from the use of resource management systems are expressed as increased timber production, increased forage on the harvest site, and benefits to other resources from improved soil and water resource management. The following are the examples of the proper implementation of resource management systems provided in Dissmeyer and Foster (1990) and Dissmeyer and Frandsen (1988). Each example begins with a hypothetical situation and then describes how management practices apply to the situation.

Example 1 focuses on soil and water resource management in road construction and maintenance. In this example, a main haul road is built across problem soils, cutbanks yield excessive surface runoff and erode easily, the runoff volume from the site is sufficient to erode through the road surface and road subgrade, road maintenance (without management practices installed) is needed every 3 years, and the road is assumed to be used for 20 years. Applying a resource management system to this situation, the following solution was devised: construct the road with midslope terraces in the cutbanks; install water diversions above the cutbanks; and seed, fertilize, and mulch the cutbanks. The total estimated repair costs over 20 years were calculated at \$2,137 for materials, labor, and cost of technical assistance. The one-time installation of management practices, which would eliminate the need

for maintenance every 3 years, would cost \$1,200. The resulting net present value, or economic benefit to the property owner, of installing the management practices in this example was calculated as \$937 (all cost figures in 1990 dollars).

Example 2 relates to recouping timber growth and yield losses through skid trail rehabilitation. Skid trails and skid roads in harvest areas are areas where sediment is lost, and as a result the timber yield in primary skid trails and on skid roads is in general severely reduced. Soils in skid trails can become severely compacted, limiting water infiltration and thus soil moisture availability and tree root development. Finally, soil nutrients are removed during skidding and during road construction. A resource management system solution to this problem involves using the following management practices: ripping and tilling the soil, waterbarring, seeding, fertilizing, and mulching. Using these practices as a system, the net present value of timber volume recovered (based on estimations provided in published studies) would be \$210 per acre based on a harvest of shortleaf pine stands and -\$237 per acre in hardwood stands. Note that the economic returns are positive in high-value shortleaf pine stands and negative in low-value hardwood stands. The study notes, however, that the herbaceous growth from applying a system of resource management practices in hardwood stands would have positive value for hunting and environmental protection.

Example 3 relates to the effect of site preparation, which can affect sediment production, soil productivity, and timber growth and yields. Poor site preparation practices that compact the soil, remove litter, and remove nutrients adversely affect soil productivity and sediment retention. The study, based on modeling data from independent studies of management practices used for site preparation, found that site preparation results in economic benefits. Specifically, investing \$50 *more* per acre in preparing a site with shearing and windrowing *reduced* future maintenance costs by \$129 per acre, compared to chopping and burning.

These examples highlight the economic and ecological advantages of using management measures and management practices as a system to reduce effects on surface waters and to ensure more rapid site regeneration and healthier timber stands.

State and Private Forestry Programs

Education and Training

Currently there are nearly 500 million acres of non-federal forests in the United States. More than 50 percent of these acres are privately owned (USDA Forest Service).

Education and training are BMPs as well. Educating and training loggers and landowners about the importance and use of management practices is an effective way to reduce water quality effects from forest operations because harvesters and landowners are responsible for forest harvesting and decisions concerning the management of much of the forested land in the Nation. A logger education program that has been adopted in various forms and under numerous names in many states is the Logger Education to Advance Professionalism (LEAP) program (APA, 1995). It is modeled after Vermont's very successful Silviculture Education for Loggers Project and began as a national pilot program of the USDA Extension Service to promote responsible

forest management practices and to teach forest ecology and silviculture to loggers. These programs are based on the premise that it is important to teach forest ecology and silviculture to loggers because professional foresters supervise less than a third of all the acres harvested in the United States while loggers are involved in all of the harvests. Before these programs, few people employed in logging had training in forestry and silviculture, and the logger education programs are changing that situation. To accomplish its goal, logger training emphasizes five areas—safety and first aid, business management, harvesting operations, professionalism, and forest ecology and silviculture.

Cooperative Forestry Programs

Cooperative Forestry is a nationwide program funded through Congress and administered nationally by the USDA Forest Service. Since 1978, the USDA has connected rural, urban, and nonindustrial private forest (NIPF) landowners with resources and ideas to assist with the care of their forests. The Cooperative Forestry program provides technical and financial assistance through partnerships with the state and private forestry organizations (USDA Forest Service, 1999). The Cooperative Forestry program was created under section 2101 of Title 16 of the United States Code, in which it is stated that it is the policy of Congress that the Secretary of Agriculture work through and in cooperation with state foresters, or equivalent state officials, nongovernmental organizations, and the private sector in implementing federal programs affecting non-federal forestlands. The landowner assistance programs covered under Cooperative Forestry are the Forest Legacy Program, the Forest Stewardship Program, and the Stewardship Incentives Program.

- *Forest Legacy Program.* This program protects private forestlands from being converted to nonforest uses. Protection is accomplished through conservation easements and purchase.
- *Forest Stewardship Program.* This program helps private forest landowners develop plans for the sustainable management of their forests. This is accomplished through active forest management for present and future landowners, increasing the economic value of the timber along with providing environmental benefits. The Forest Service also provides public outreach programs to assist NIPF landowners with information regarding seedling production and tree stand improvements.
- *Stewardship Incentives Program.* This program provides cost-share financial assistance to private landowners to carry out their forest stewardship plans. It encourages multiresource forest practices. These practices encompass reforestation of harvested lands, creating windbreaks, thinning, and habitat improvements for wildlife and fisheries. The production of high-quality, genetically improved tree seed and planting stock is a further function of multiresource practices. Technical and financial assistance is also provided for state foresters for product delivery.

Nonindustrial private ownership of timberland in the United States is 58 percent. Of this, 29 percent is owned by farmers. The rest of the timberland in the United States is owned by the federal government (20 percent), the forest industry (14 percent),

state government (6 percent), and counties and municipalities (2 percent). Because of the large percentage of timberland owned by nonindustrial private landowners, an important part of protecting forests and water quality during forest harvest is educating those landowners about forest management and proper timber harvesting techniques to protect water quality (Powell et al., 1994). Some private landowners may not place an emphasis on water quality protection when planning a harvest because it appears to provide benefits only for downstream users, not for the harvesting landowner. Other management measures, such as site preparation to improve regeneration, provide direct benefits to landowners and are therefore more likely to be part of the landowner's harvest plan (Alden et al., 1996).

A survey to compare the attitudes of persons involved with forestry program administration and implementation about the effectiveness of various approaches to protecting water quality and forests in general rated methods for protecting water quality from most effective to least effective as follows (Ellefson et al., 1995): technical assistance, fiscal incentives, educational programs, voluntary programs, regulatory programs, and tax incentives (Figure 2-6).

In this survey, forestry program administrators were asked to rate specifically the effectiveness of educational programs for protecting water quality: 19 were neutral about their effectiveness, 17 said that they thought they were effective, and 12 thought that they were ineffective. The results for a similar rating of the effectiveness of technical assistance programs for protecting water quality showed that 26 administrators thought they were effective, 17 were neutral about their effectiveness, and 6 thought them to be ineffective.

The importance of education in forest harvesting and forest stewardship can be judged from the fact that many state departments of forestry have BMP guidebooks and education programs geared not only to loggers and industrial owners but also to the landowners who are not trained in forest management and harvesting. A review of some states' educational programs is provided below, and this review represents the variety of educational and technical assistance programs offered by states and the importance states place on education.

Washington State

Forest Stewardship is a nationwide program designed to assist nonindustrial private forest owners in managing their properties for a variety of resource values. Assistance is customized to meet the specific needs and objectives of the landowner who requests assistance. In Washington State the program is funded and administered by the USDA Forest Service and the Washington State Department of Natural Resources (DNR) in close cooperation with several other state and federal agencies and private organizations. The Washington State University Cooperative Extension conducts the statewide Forest Stewardship Educational Program for landowners in Washington. The *Forest Stewardship Notes* newsletter is distributed statewide to interested landowners (Washington State DNR, 1997).

Additionally, forest owners with at least 5 forested acres in the state of Washington can request on-site assistance from a DNR stewardship forester and wildlife biologist. The USDA Natural Resources Conservation Service and local Conservation Districts also assist forest owners in many areas of the state.

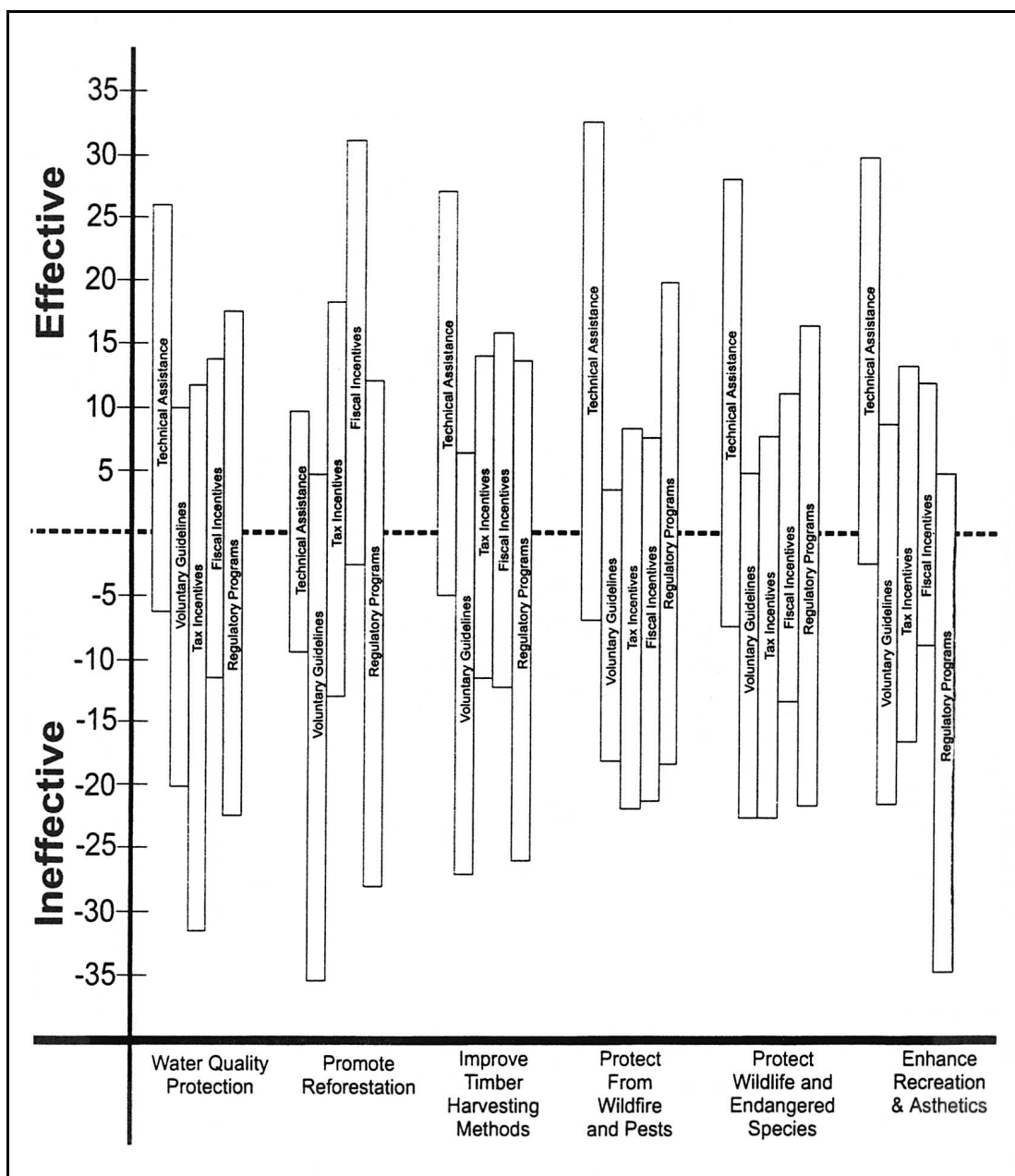


Figure 2-6. Ratings of the effectiveness of various types of programs for accomplishing specific forestry objectives. Height of line above or below the centerline indicates the number of state program administrators who rated the program type as effective or ineffective, respectively, for accomplishing the specific objective (Ellefson et al., 1995).

Virginia

The Virginia Department of Forestry (DOF) reports that surveys show most landowners sell timber and make other forest management decisions without professional advice. These same studies have demonstrated that landowners who sell timber with the assistance of a professional forester receive 50 percent more for their timber. Since professional foresters are knowledgeable of water protection BMPs, having a landowner contact a professional benefits both the landowner and the environment (Virginia Department of Forestry, 1998).

A service to landowners in Virginia is the availability, free of charge, of Virginia DOF foresters in every county to provide Management Plans for timberland owners. Each plan is a resource inventory of tree species composition, age, merchantability, growth rate, and wildlife habitat conditions, and it contains recommendations of methods for protecting water quality and sensitive natural areas. The DOF recommends BMPs to loggers and landowners in preharvest planning, focusing on preservation of streamside management zones of undisturbed timber, proper log road layout, and wetlands protection. The Department, forest industry, and consultant foresters cooperate in monitoring harvest operations to encourage proper stream crossings, installation of water diversion devices, seeding of log roads with grass cover, and maintenance of streamside forest.

During a logging operation, the logger, the forester, and/or the landowner are also contacted concerning BMP installation. The DOF inspects harvesting sites for compliance with the state's Silvicultural Water Quality Law. Landowners are also contacted concerning needs for forest renewal and future management.

Tennessee

Forestry assistance in Tennessee is handled by the Tennessee Department of Agriculture (DOA). DOA trains loggers and others involved in land management in the use of logging techniques to prevent erosion and leave streams unharmed. Tennessee DOA has also developed a number of training aids for water quality, including a video, printed material, and a number of forest management demonstration sites. One of DOA's primary services is offering advice to landowners, often in person on the individual's property. All topics that relate to managing a forest—including timber stocking and health, timber sale planning and harvest, soil and water protection, forest regeneration, wildlife management, and cost sharing—are discussed with landowners in the belief that educated forest landowners protect the environment better than uneducated ones (Tennessee DOA, 1998).

DOA also administers the nationwide Forest Stewardship Program (see discussion above under Washington) in Tennessee. Additionally, in 1993 DOA implemented the Forestry Water Quality Initiative, which focuses on increasing the use of BMPs and providing technical assistance to individual loggers and forest landowners. The initiative has been very successful. More than 3,000 foresters, loggers, and landowners have received formal training and technical assistance in the use of BMPs since the initiative began.

Another excellent training program available to loggers is the Master Logger Program. The mission of the Master Logger Program is "to enhance the professionalism of the Tennessee logger" through a complete educational program designed to improve the health and well-being of the logging industry and the forest resource. The Master Logger curriculum consists of five 1-day courses, one of which is on forest ecology and BMPs. Loggers attend individual sessions of the program 1 day every 2 weeks, and it takes 10 weeks to complete the workshop. Many other states provide programs similar to the Master Logging Program under various names, and all of the programs stem from the original pilot program of the USDA Extension Service, the LEAP program.

Oregon

Nearly 24,000 forest operations are conducted each year on state and private land, double the number 10 years ago. The largest number of operations occur on small private forests where the landowners are typically not as familiar with the state's forest practice rules as are large industrial landowners. The state therefore puts a great deal of energy into providing information, training, and resources to landowners and operators (Oregon DOF, 1997).

The Oregon Department of Forestry's Forest Practices Program involves more than 150 people in the department's main offices and in field offices who provide face-to-face information and guidance to landowners. Program staff work with industry and environmental representatives to develop programs and incentives for encouraging sound stewardship of forest resources.

South Carolina

The South Carolina Forestry Commission provides timber management assistance to forest landowners in the state. Forestry Commission foresters will examine forestland and potential forestland at the request of a landowner. A written plan and map are prepared for the landowner, giving forest management recommendations that best meet the owner's needs and objectives, provided that they are compatible with good forest management practices (South Carolina Forestry Commission, 1998).

Two-thirds of the state's forestlands are under private ownership, and the South Carolina Forestry Commission provides assistance to these landowners geared toward educating them so that they can take an active role in managing their forests. Anyone who owns at least 10 acres of forestland can qualify for assistance under the program. A South Carolina Forestry Commission staff member will help the landowner put together a multiple-resource Stewardship Management Plan (SMP) that provides detailed recommendations for timber management activities designed to help prevent soil erosion and protect water quality and might also provide details on wildlife habitat improvement.

Ohio

The Ohio Forestry Association maintains a Safety Training and Certification Program for logging contractors and their employees. It is the Ohio equivalent of a LEAP program. One of the requirements for certification as a Certified Logging Company is to have employees who have been trained to use BMPs to reduce soil erosion and improve the appearance of timber harvesting activities (Ohio Forestry Association, 1999).

California

The California Department of Forestry & Fire Protection (CDF) operates the California Forest Stewardship Program. The program, like similar programs in other states, is designed to encourage good stewardship of private forestland and focuses on providing technical and financial assistance in forestland management and community assistance in solving common watershed problems. The CDF has a

Forest Stewardship Helpline (1-800-738-TREE) that landowners can call for answers to forest management questions and referrals on any forest-related topic. A quarterly newsletter, *Forestland Steward*, is circulated to provide information on topics of interest to landowners and others. The Forest Stewardship Program provides financial and technical assistance, demonstration projects, and a landowner curriculum that might include conferences, workshops, and other programs (CDF, 1998).

Maine

The Forest Policy and Management Division of the Maine Department of Conservation, Forest Service provides technical assistance, information, and educational services to forest landowners. Part of the Division's implementation of the Forest Practices Act is providing educational workshops, field demonstrations, and media presentations, and contacting landowners personally to discuss forest management issues (Maine DOC, 1998).

North Dakota

The majority of North Dakota's rural forests are privately owned. Forest resource management in the state focuses on education and assisting nonindustrial private landowners to better manage, protect, and use their natural resources. This is accomplished through the development of a forest stewardship plan and direct financial assistance for forest improvement practices. Rural forestry services are delivered through an agreement with North Dakota's local Soil Conservation Districts (NDSU, 1998).

The Stewardship Incentive Program (SIP) and the Agricultural Conservation Program (ACP) offer up to 75 percent cost-share assistance to landowners for accomplishing forest stewardship projects such as tree planting, forest stand improvement, soil and water protection, riparian protection, windbreak renovation, and wildlife habitat enhancement.

Technical assistance is provided to more than 1,300 rural landowners each year. Since 1991, forest stewardship plans have been requested and completed for 41,330 acres of privately owned native and planted woodlands.

Missouri

The Missouri Department of Conservation (MDC) provides forest management service to landowners for long-term management and stewardship of their forestland. Persons who receive management assistance from the MDC agree to develop and implement a management program for their property. Management plan implementation activities include guidance in soil and watershed protection, erosion control, wildlife habitat improvement, and forest road location and construction. A visit to the landowner's property is part of MDC's assistance in management plan development (Missouri DOC, 1990).

Sustainable Forestry Initiative

The approximately 200 member companies of the American Forest and Paper Association (AF&PA), the national trade association for the forest products industry, approved a comprehensive set of Sustainable Forestry Principles and Implementation Guidelines, referred to as the Sustainable Forestry Initiative (SFI), in October 1994. The SFI principles and guidelines are a means for member companies to continually improve forestry management and by which the public can assess the commitment of the member companies to the principles and their progress in their implementation. The guidelines require that SFI program participants meet or exceed all established EPA-approved BMPs, all applicable state water quality laws and regulations, and the requirements of the Clean Water Act for forestland.

The guidelines also include practices by which member companies reach loggers and nonindustrial landowners. Since 58 percent of the timberland in the United States is owned by more than 10 million private nonindustrial landowners, an important goal (like that of the LEAP program, discussed above) is to reach and educate them with respect to sustainable forestry practices. Educating loggers serves not only to improve their stewardship of the land but also to educate private nonindustrial landowners, since loggers are the landowners' primary source of information on forestry and silviculture.

Member companies submit annual reports to AF&PA describing their progress in implementing the SFI principles and Action Plan. This assists AF&PA in tracking indicators of environmental performance, including harvest method, percent of raw material delivered by trained loggers, research funding, and timetables for reforestation of harvested areas. These data are being collected to identify trends in the practice of sustainable forestry such as increases in the use of harvesting best management practices and changes in wildlife habitat diversity on members' forestland. More information on the SFI can be found in Appendix C.

The Society of American Foresters' Certified Forester® Program

The Society of American Foresters (SAF), a nonprofit, scientific, and educational organization, established the Certified Forester® (CF) program in 1994. The term *Certified Forester* is registered with the U.S. Patent and Trademark Office and may only be used by individuals who meet SAF's certification requirements. The CF program is voluntary, nongovernmental, and open to qualified SAF members and nonmembers. A Certified Forester agrees to abide by current CF program requirements and procedures for certification and recertification; to maintain continuing professional development; and to conduct all forestry practices in a responsible, professional manner consistent with state and federal regulations governing environmental quality and forest management practices.

Through the CF program and other activities, SAF advocates wise stewardship in forest resources management. The CF program provides a consistent, national credential. Certification constitutes recognition by SAF that, to the best of SAF's knowledge, a Certified Forester meets and adheres to certain minimum standards of academic preparation, professional experience, continuing education, and

professionalism. No individual is eligible to receive or to maintain Certified Forester status or recertification unless the individual meets and continues to adhere to all requirements for eligibility. Some of the requirements that must be met by all CF applicants can be found in Appendix C.

Effectiveness of Education and Technical Assistance

Researchers with the U.S. Forest Service reviewed state BMP implementation and monitoring programs and the results from those programs in 1994. At the time, 21 states were assessing BMP effectiveness. The U.S. Forest Service found that the states had generally concluded that carefully developed and applied BMPs can prevent serious deterioration of water quality and that the availability of well-qualified personnel at the field level is probably the most cost-effective approach to meeting water quality standards. Most water quality problems, they found, were associated with poor BMP implementation, and trained field personnel could help correct problems with implementation (Greene and Siegel, 1994).

The researchers also concluded that an iterative self-education process at the state level was important for BMP improvement. Water quality monitoring is essential to understanding the relationship between land disturbance and water quality, they found, and it leads to improved understanding of the interaction of soils and topography with BMP implementation. This understanding was considered essential to continually reassessing BMP guidelines to make them more cost-effective. BMPs need to be specified, used, monitored, and fine tuned to provide cost-effective water quality protection.

Ellefson and others (1995) reviewed forest practice programs in many states, and one aspect of their review involved asking program managers what they thought were the most effective means to protect water quality. State program managers rated the following in program effectiveness, from most effective to least effective: technical assistance, fiscal incentives, educational programs, voluntary programs, regulatory programs, and tax incentives. For promoting reforestation and improving timber harvesting methods, technical assistance and fiscal incentives were rated as the most effective means and regulatory programs and voluntary guidelines were rated as the two least effective.

When the Vermont Agency of Natural Resources (ANR) studied BMP implementation and effectiveness, ANR personnel accompanied harvesters in the field during harvests. During the harvests monitored, logging personnel appeared to become much more aware of the water quality issues related to their activities and the intent of the BMPs. By the end of the project, the loggers were extremely conscientious in their efforts to protect water quality. Vermont ANR personnel felt that without the oversight of the forestry agency, it was likely that water quality problems would have been more severe, particularly in the early phase of the project. After the assistance provided by the personnel, managers for the logging companies were fully capable of implementing appropriate BMPs with little or no oversight.

Cost Estimates for Forest Practice Implementation

Estimates of the per acre cost of implementing BMPs for timber harvests were arrived at based on information obtained from published reports on regional studies of the cost of BMP implementation and cost estimates based on the regulatory structure of forestry practice programs. Studies have been conducted on the cost of implementing forestry practices for water quality and soil protection in the Southeast and some western states (Aust et al., 1996; Dissmeyer and Foster, 1987; Dubois et al., 1991; Henly, 1992; Lickwar, 1989; Olsen et al., 1987). Costs associated with complying with forest practices in states where their implementation is either voluntary or regulated, with differing numbers and types of requirements depending on the state, have also been estimated (Table 2-2) (Ellefson et al., 1995).

Table 2-2. Estimations of Overall Cost of Compliance with State Forestry BMP Programs by Program Type.

| Applicability | Cost Estimation ^a | Reference |
|--|--|--|
| Virginia and southeastern states (applicable to central and northern states) | Voluntary-to-mandatory implementation (\$) | Aust et al., 1996 |
| | Coastal plain region: = \$11.70 per acre | |
| | Piedmont region: = \$30.40 per acre | |
| | Mountain region: = \$44.50 per acre | |
| | Stringent/Enforceable implementation (\$) | |
| | Coastal plain region: = \$21.40 per acre | |
| California | Piedmont region: = \$38.00 per acre | Henly, 1992 |
| | Mountain region: = \$49.10 per acre | |
| | Average cost = \$250 per acre | |
| | Inland areas = \$81 - \$414 per acre ^b | |
| Oregon, Washington, Alaska | Coastal areas = \$460 per acre ^b | Ellefson et al., 1995 (Division between coastal and noncoastal based on California model) |
| | Average cost = \$175 - \$373 per acre | |
| | Noncoastal areas = \$175 per acre | |
| | Coastal areas = \$373 per acre | |
| Nevada, New Mexico, Idaho | Other western states with forest practice regulation. Cost per acre is estimated as the average of costs in western states without forest practice regulation and the low-end cost given for Oregon noncoastal forests: | |
| | $(\$125 + \$175)/2 = \$150 \text{ per acre}$ | |
| Arizona, Colorado, Montana, Utah, Wyoming, Hawaii | Western states without forest practice regulation. Cost per acre is estimated as one-half of California's noncoastal cost: | |
| | $\$250/2 = \125 per acre | |

^a All costs in 1998 dollars.

^b Excluding most costly scenario.

Some cost information for forest practice implementation is based on the average increased cost of conducting a harvest when management measures, i.e., a suite of practices, are used versus when they are not used (Table 2-3). Costs provided in this

Table 2-3. Estimations of Implementation Costs by Management Measure in the Southeast and Midwest.

| Practice | Average Cost ^a | Cost Range | Comments | Reference |
|--|---------------------------|--|--|--|
| Planning | | | | |
| Savings from road design/location | (\$385/mi) | | Savings were associated with avoiding problem soils, wet areas, and unstable slopes. Maintenance savings resulted from revegetating cut and fill slopes, which reduced erosion. Southern states. | Dissmeyer and Foster, 1987 |
| Savings in maintenance | (\$231/mi) | | | |
| SMA | \$3,996 | | Costs for average tract size of 1,361 ac; include marking and foregone timber value. Southern states. | Lickwar, 1989 |
| Road Construction | | \$5,301/mi - \$42,393 | Lower end for no gravel and few culverts; upper end for complete graveling and more culverts. West Virginia. | Kockenderfer and Wendel, 1980 |
| | | \$14,801 - \$42,393 | Lower end for 1,832-ac forest with slopes <3%; upper end for 1,148-ac forest with slopes >9%. Southern states. | Lickwar, 1989 |
| | | \$229/mi - \$11,604/mi | Lower end for grass surfacing; upper end for large stone surfacing. Appalachia. | Swift, 1984 |
| Construction Phase (as percent of total cost) | -- | 10% 20 - 25% 20 - 25% 10% 30 - 40% | Equipment and Material Clearing, grubbing, and slash disposal Excavation Culvert installation Rock surfacing | USDA-SCS, cited in Weaver and Hagans, 1994 |
| Road Maintenance | \$2,205-\$3,941 | | Lower end for roads constructed without BMPs; upper end for roads constructed with BMPs. Costs over 20 years discounted at 4%. | Dissmeyer and Frandsen, 1988 |
| Mechanical Site Preparation | \$140/ac | \$77/ac - \$281/ac | Lower end for disking only; upper end for shear-rake-pile-disk. Southern states. | Dubois et al., 1991 |
| | | \$75/ac - \$180/ac | Lower end for light preparation, including hand; upper end for chemical-mechanical site preparation. | Minnesota, 1991 |
| Regeneration | | \$84/ac - \$355/ac | Lower end for direct seeding; upper end for tree planting with purchased planting stock. | Illinois, 1990 |
| | \$50/ac | \$48/ac - \$60/ac | Lower end for machine planting; upper end for hand planting. Southern states. | Dubois et al., 1991 |
| Revegetation | \$22,741 | | Cost for average sized tract of 1,361 ac; includes seed, fertilizer, mulch. Southern states. | Lickwar, 1989 |
| | | \$132/ac - \$239/ac | Lower end for introduced grasses; upper end for native grasses. Includes seedbed preparation, fertilizer, chemical application, seed, seedlings. | Minnesota, 1991 |
| Prescribed burning | \$13/ac | \$10/ac - \$19/ac | Lower end for windrow burning; upper end for burning after chemical site preparation. Southern states. | Dubois et al., 1991 |
| Pesticide application | \$102/ac | \$56/ac - \$138/ac | Lower end for ground application; upper end for aerial application. Southern states. | Dubois et al., 1991 |
| Fertilizer application | \$63/ac | \$43/ac - \$73/ac | Lower end for ground application; upper end for aerial application. Southern states. | Dubois et al., 1991 |

^a All costs in 1998 dollars.

way emphasize the difficulty in separating the costs of implementing individual forest practices. This difficulty is due to incorporating the cost of using numerous BMPs into the accomplishment of a single harvesting or road construction activity, and spreading the cost for individual practices across the accomplishment of multiple activities. For example, the cost of adhering to a state regulation for stream crossings might be spread among the costs of planning a harvest to minimize the number of stream crossings, designing and constructing forest roads to accommodate the plan and minimize instream effect to water quality and fish, and the actual construction of the stream crossings. Furthermore, these costs differ with each harvest because the terrain, soils, location of harvest site relative to streams, and hydrology are different at each harvest site. Therefore, all costs presented here are best regarded as rough estimates.

The costs of implementing state forest practices arise from conducting timber surveys, preparing management plans, constructing roads, and implementing practices specifically designed to protect water quality. Many of these costs are borne whether or not a stream or other surface water is located on or near a harvest site, though additional costs (e.g., designing and flagging an SMA, constructing stream crossings) are incurred where streams are present. Costs also take the form of lost revenue from trees that are not harvested to ensure compliance with forest practices. Revenue might be reduced if merchantable trees are left standing in SMAs or when selective cutting is called for rather than clear-cutting. Although the loss of revenue is a real “cost” to landowners, it is very market- and species-dependent and is generally not included in the cost estimates provided here. The overall costs of complying with regulatory forestry management practice programs might be borne by forest landowners alone or shared among landowners, timber operators, and others (Figure 2-7).

Factors that typically affect the cost of implementing forest practices include the type of terrain on which a harvest occurs (with costs for harvesting on steeper terrain typically being higher than costs for harvesting on flatter terrain) and the regulatory structure of forest practice rules. Compliance in states that have numerous and stringent forest practice regulatory requirements generally costs more than

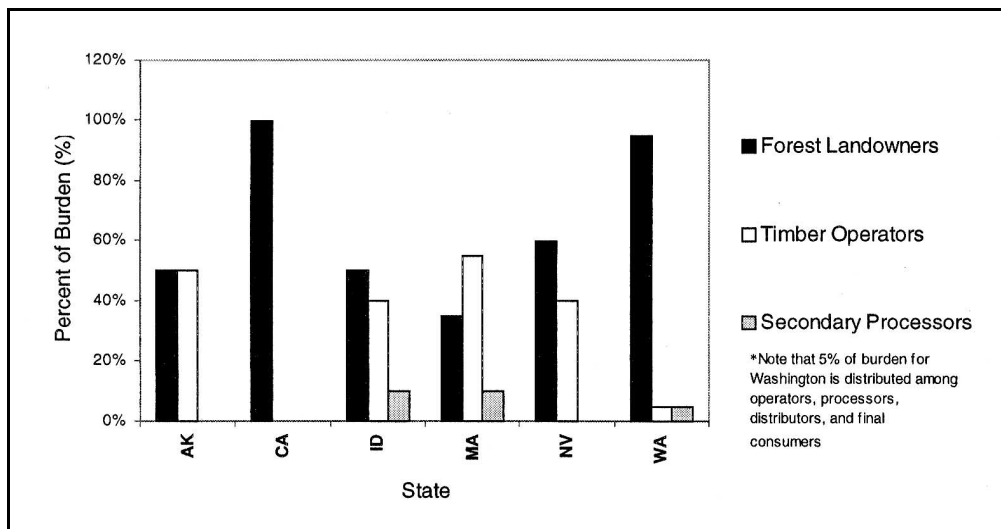


Figure 2-7. Distribution of the cost of regulatory programs among different groups in representative states (Ellefson et al., 1995).

compliance in states where regulatory requirements are fewer or less stringent, or are voluntary. Some states have single regulations that can add significantly to the cost of forest harvesting. An example is the requirement for a detailed forest harvest plan in California. This alone places compliance with forest practices in California in a category by itself.

Table 2-2 summarizes estimations of the overall per-harvest cost of complying with forest practice regulations in different regions and states. Table 2-3 provides cost estimates for implementation of individual management measures in the Southeast and Midwest. The costs, updated to 1998 dollars, have been verified with state and federal forest management agencies and have been found to be representative of actual expenditures. Although most of the cost information came from case studies in the southeastern United States, they are representative of costs incurred nationwide. Costs vary depending on the site-specific nature of the timber harvesting area. Table 2-4 provides estimates of costs for installing individual road construction and erosion control BMPs. Costs are provided by region. Factors that affect implementation costs are mentioned in the *Comments* column.

Other costs, where available, are provided for individual management measures or management practices within the appropriate discussions in Chapter 3.

Table 2-4. Estimations of Construction and Implementation Costs for Individual BMPs, by Region.

| BMP | Approximate Construction and Implementation Costs per BMP Installed, by Region | | | | | | | Comments |
|-----------------|--|------------------------------|-------------------------------|--|---|------------------------------|--------------------------------|---|
| | Northeast ¹ | Southeast ² | Midwest ³ | Rocky Mountains ⁴ | Northwest ⁵ | Southwest ⁶ | Alaska ⁷ | |
| Broad-based dip | | \$40 | \$40 - \$90 | \$50 - 60 | \$25 - 35 | \$100 - \$130 | \$30 - \$40 | Depends on the cost of labor, equipment, and terrain (Northwest costs include profit and overhead). |
| Waterbar | | \$20 (not including labor) | \$60 - \$75 (on skid trails) | n/a | \$100 | \$45 - \$60 | \$25 - \$35 | Cost varies with size and construction material. |
| Mulch | | \$71 (ton) | \$20 - \$80 (ton) | n/a | \$1,500 (ac)(hydro-mulch) | \$400 - \$500 (ac) | \$80 - \$90 (ton) | Cost varies with regional market price and haul distance. |
| Seed | \$1,000 (ac) (hydro-seed) | \$1 - \$6 (lb) | \$0.50 - \$10 (lb) | \$6 (lb) | \$400 - \$450 (ac) | \$200 - \$400 (ac) | \$7 - \$10 (lb) | Cost varies with species of seed, regional market price, and terrain. |
| Riprap | | n/a | \$5 - \$10 (yd ³) | \$21 (yd ³) | \$15 - \$30 (yd ³) | n/a | \$19 - \$37 (yd ³) | Price varies with size of rock used. |
| Gravel | | \$6 - \$10 (ton) | | \$35,000-\$40,000 (mile, 14' W x 4" D) | \$16 - \$26 (yd ³) | \$30 (yd ³) | \$18 - \$22 (yd ³) | Cost varies with the size of rock and haul distance. |
| Culvert | | \$420 | \$500 - \$2,000 | \$19 (ft, 18" pipe) | \$26 (ft, 24" pipe) \$100 (ft, 72" pipe) | \$24 (ft, 18" pipe) | \$23 (ft, 18" pipe) | Cost varies with size and length of culvert. Costs provided reflect base cost for installation. |
| Straw Matting | | \$56 (roll, 7.5' x 120') | | n/a | \$2 (yd ²) | \$1 - \$3 (yd ²) | \$2.50 (yd ²) | Cost varies with size of matting. |
| Geotextiles | | \$378 (700 yd ²) | \$2 - \$6 (ft) | \$8 - \$12 (ft) | \$1 - \$2 (ft) | n/a | \$14 (ft) | Woven geotextiles are the only geotextile recommended for road-stream crossings. |

Table 2-4. Estimations of Construction and Implementation Costs for Individual BMPs, by Region (cont.).

| BMP | Approximate Construction and Implementation Costs per BMP Installed, by Region | | | | | | | Comments |
|-------------------------|--|------------------------|----------------------|------------------------------|------------------------------------|------------------------|------------------------|---|
| | Northeast ¹ | Southeast ² | Midwest ³ | Rocky Mountains ⁴ | Northwest ⁵ | Southwest ⁶ | Alaska ⁷ | |
| Hardwood Mats (pallets) | \$120 - \$200 | \$120 - \$200 | \$170 (10' x 12') | \$120 - \$200 | \$120 - \$200 | \$120 - 200 | \$155 (10' x 12') | Cost varies with size. |
| Turn-outs | \$40 - \$50 | \$50 - \$70 | \$50 - \$70 | \$50 | \$50 | \$40 - \$50 | \$71 | Cost varies with equipment and labor costs. |
| Silt Fence | | \$24 (24" H x 100' L) | not commonly used | not commonly used | \$1.50 (yd ²) | \$4 (ft) | \$2 (yd ²) | Cost varies with regional prices and length. |
| Dust Control | \$1,000 (mile, using calcium chloride) | | | | \$1,000 - \$3,000 (mile, annually) | \$190 (ton) | | Varies widely with traffic level. |
| Temporary Bridge | | \$500 - \$20,000 | \$500 - \$15,000 | \$200 - \$25,000 | \$1,000 - \$2,000 (ft) | n/a | \$1,250 - \$2,500 (ft) | Cost varies widely with quality of materials used, width, and span. |
| Barge (Alaska) | -- | -- | -- | -- | -- | -- | \$1,000 (hr) | Barge transport in southeastern Alaska (Tongass Natl. Forest) is the most common means to deliver material to a site. |

All costs are per unit provided (ac = acre; ft = linear foot; hr = hour; lb = pound; yd² = square yard; yd³ = cubic yard; D = depth; H = height; L = length; W = width).

Where units are not provided, cost is per BMP installed.

¹ Schmid, 2000

² Holburg, 2000; Marzac, 2000

³ Hansit, 2000; Gambles, 2000

⁴ Taylor, 2000

⁵ Dorn, 2000; Hulet, 2000; Wilbrecht, 2000; Yoder, 2000

⁶ Leyba, 2000

⁷ Jenson, 2000

Scope of This Chapter

For the purposes of this guidance, EPA has addressed the activities associated with forest harvesting that could affect water quality through nine management measures. A separate management measure is applicable specifically to wetlands in forested areas. The management measures are stated as steps to be taken, guidelines for operations, or goals to be achieved for protecting water quality during the related phases or activities. The following are EPA's silvicultural management measures:

- Preharvest planning
- Streamside management areas
- Road construction/reconstruction
- Road management
- Timber harvesting
- Site preparation and forest regeneration
- Fire management
- Revegetation of disturbed areas
- Forest chemical management
- Wetland forest management

Numerous management practices are associated with each management measure. Management practices are specific actions, processes, or technologies that can be used to achieve a management measure. These practices are very similar to those recommended by most states; because of the national scope of this guidance, however, some of the particulars of implementation (such as prescriptions for sizes of pipes, lengths of road at particular slopes, and other such site- or region-specific details) are not included as part of the descriptions of management practices. Implementation of one or more management practices is usually necessary to achieve the level of pollution control intended by a single management measure.

Each management measure is addressed in a separate section of this chapter. Each section contains the wording of the management measure, which has not been changed from that in the 1993 CZARA guidance; a description of the management measure's purpose or how it can be used effectively to protect water quality; and information on management practices that are suitable, either alone or in combination with other practices, to achieve the management measure. Where new or improved versions of management practices have been developed, they have been discussed in this guidance. Many of the management practices were in the 1993 CZARA guidance, and most can be found in state forest practices manuals. For recommendations on widths of streamside management areas, slopes and lengths of culverts, and other criteria for your specific area, consult a state forest practices manual or contact your local forester.

Since the silvicultural management measures developed for the CZARA are for the most part a system of practices commonly used and recommended by states and the U.S. Forest Service, many management practices are already being implemented at many harvest sites and on many forest roads. Where the measures in place are inadequate to

protect water quality, augmenting them with additional or complementary practices might be all that is necessary. Where measures are lacking and water quality is or might become impaired, this guidance can help you choose practices suitable to the source of water quality impairment.

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3A: Preharvest Planning

Management Measure for Preharvest Planning

Perform advance planning for forest harvesting that includes the following elements where appropriate:

- (1) Identify the area to be harvested including location of waterbodies and sensitive areas such as wetlands, threatened or endangered aquatic species habitat areas, or high-erosion-hazard areas (landslide-prone areas) within the harvest unit.
- (2) Clearly mark these sensitive areas with paint or flagging tape, or in another highly visible manner, prior to harvest or road construction.
- (3) Time the activity for the season or moisture conditions when the least effect occurs.
- (4) Consider potential water quality effects and erosion and sedimentation control in the selection of silvicultural and regeneration systems, especially for harvesting and site preparation.
- (5) Reduce the risk of occurrence of landslides and severe erosion by identifying high-erosion-hazard areas and avoiding harvesting in such areas to the extent practicable.
- (6) Consider additional contributions from harvesting or roads to any known existing water quality impairments or problems in watersheds of concern.

Perform advance planning for forest road systems that includes the following elements where appropriate (Figure 3-1):

- (1) Locate and design road systems to minimize, to the extent practicable, potential sediment generation and delivery to surface waters. Key components are:
 - locate roads, landings, and skid trails to avoid to the extent practicable steep grades and steep hillslope areas, and to decrease the number of stream crossings;
 - avoid to the extent practicable locating new roads and landings in Streamside Management Areas (SMAs); and
 - determine road usage and select the appropriate road standard.
- (2) Locate and design temporary and permanent stream crossings to prevent failure and control effects from the road system. Key components are:
 - size and site crossing structures to prevent failure;
 - for fish-bearing streams, design crossings to facilitate fish passage.
- (3) Ensure that the design of road prism and the road surface drainage are appropriate to the terrain and that road surface design is consistent with the road drainage structures.
- (4) Identify and plan to use road surfacing materials suitable to the intended vehicle use for roads that are planned for all-weather use.
- (5) Design road systems to avoid high erosion or landslide hazard areas. Identify these areas and consult a qualified specialist for design of any roads that must be constructed through these areas.

Each State should develop a process (or utilize an existing process) that ensures that the management measures in this chapter are implemented. Such a process should include appropriate notification, compliance audits, or other mechanisms for forestry activities with the potential for significant adverse nonpoint source effects based on the type and size of operation and the presence of stream crossings or SMAs

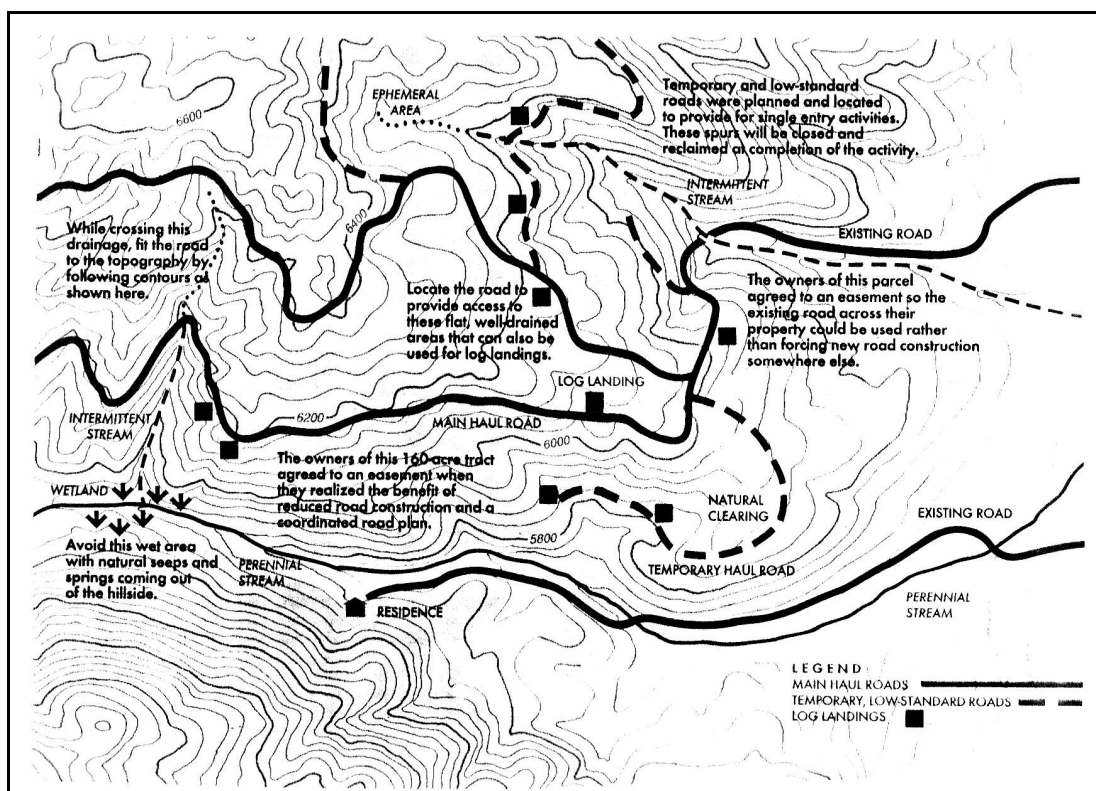


Figure 3-1. Topographic maps are helpful during preharvest planning for laying out roads, landings, streamside management areas, sensitive habitats, and connections to public roads (Montana State University, 1991).

Management Measure Description

The objective of this management measure is to ensure that silvicultural activities, including timber harvesting, site preparation, and associated road construction, are conducted without significant nonpoint source pollutant delivery to streams, other surface waters, or coastal areas. Road system planning is an essential part of this management measure because road building is the main destabilizing activity carried out in forestry, and avoidance is the most cost-effective means of dealing with unstable terrain (Weaver and Hagans, 1994). A basic tenet of road planning is to minimize the number of roads constructed in a watershed through basin-wide planning. Good road location and design can greatly reduce the sources and transport of sediment. Road systems can be designed to minimize the number of total road miles or acres, the size and number of landings, the number of skid trail miles, and the number of watercourse crossings, which is especially important in sensitive watersheds. Minimizing a road system's infrastructure through careful planning can also save dramatically on costs. A cost-benefit analysis by Dissmeyer and others (USDA, 1987) demonstrated immediate savings from considering water quality during the design phase of a road reconstruction project (Table 3-1). Timing operations to take advantage of favorable seasons or conditions and thus avoiding wet seasons when the soils are prone to severe erosion and seasons when fish are spawning is one effective element of preharvest planning that can reduce effects to water quality and aquatic organisms (Hynson et al., 1982).

Table 3-1. Costs and Benefits of Proper Road Design (with Water Quality Considerations) versus Reconstruction (without Water Quality Considerations) (USDA Forest Service, 1987).

| | Without Soil/ Water Input ^a | With Soil/Water Input ^a |
|---|--|------------------------------------|
| Miles of road | 3.0 | 3.0 |
| Reconstruction costs | \$1,184,000 | \$553,314 |
| Soil/water input costs | -- | \$1,190 |
| Immediate benefit (savings) of soil/water input | -- | \$315,259 |

All costs updated to 1998 dollars.

^a Soil/water inputs are design adjustments made by a hydrologist and include narrower road width and steeper road bank cuts in soils of low erodibility and low revegetation potential.

Preharvest planning is an excellent opportunity to identify areas unsuitable for disturbance, such as sites with seasonal limitations. For example, some wet areas can be harvested when frozen, while some dry areas are too wet to work during periods of high

precipitation. An area that has merchantable trees but which poses an unacceptable risk for landsliding or which has a high erosion hazard rating is another example of an area that might be unsuitable for disturbance. Steep slopes in areas with high rainfall or snowpack or unstable bedrock are examples of areas to avoid. Decomposed granite, highly weathered sedimentary rocks, and fault zones in metamorphic rocks are rock types where landslides might be more likely. Deep soils derived from these rocks, colluvial hollows, and fine-textured clay soils are soil conditions that might also cause problems. Such areas usually have a history of landslides, occurring naturally or related to previous land-disturbing activities.

Road System Layout: The general concepts to follow are “less is best” and “avoid the worst” (Weaver and Hagans, 1994):

- Minimize total road miles in your watershed.
- Minimize new road construction by using existing roads.
- Minimize construction of permanent and seasonal roads by using these standards only when absolutely necessary; use temporary roads to minimize long-term maintenance and reconstruction costs and reduce environmental damage.
- Strictly minimize the number of watercourse crossings.
- Minimize cuts, fills, and vegetation clearing by contouring roads across the landscape.
- Minimize road work near SMAs and on unstable areas, inner gorges, and steep slopes.
- Minimize road width.
- Minimize road gradient.
- Minimize the concentration of runoff on and from the new road.
- Avoid problem areas and serious obstacles, when possible.

Preharvest planning includes consideration of the potential water quality and habitat effects of the component parts of the harvest, including the harvesting system (e.g., even-aged—clearcut, seed tree, or shelterwood, or uneven-aged—group selection or individual tree selection); the yarding system (e.g., skyline cable, ground skidding); existing roads and newly constructed roads; management practices and drainage structures to be used to keep the road system, yarding areas, and skid trails hydrologically disconnected from surface waters; regeneration of the harvest site; and other aspects of the harvest.

Much has been written about clearcutting versus selective cutting. Each have their own particular purposes in forest harvesting and regeneration. From a water quality perspective, the numerous factors that are involved with each harvesting system have to be weighed to estimate which system will have fewer water quality effects for any given harvest. Table 3-2 displays data from a study that compares water yield and sediment

Table 3-2. Clearcutting versus Selected Harvesting Methods in Arkansas (after Beasley and Granillo, 1985).

| Water Year | Treatment | Mean Annual Water Yield (in) | Mean Annual Sediment Losses (ton/ac) |
|----------------------|-----------|------------------------------|--------------------------------------|
| 1981 (Preharvest) | Clearcut | 2.5 | .02 |
| | Selection | 2.9 | .02 |
| | Control | 2.7 | .02 |
| 1982 | Clearcut | 5.2 | .12 |
| | Selection | 2.0 | .01 |
| | Control | 0.4 | -- |
| 1983 | Clearcut | 17.6 | .03 |
| | Selection | 13.3 | .01 |
| | Control | 12.2 | .01 |
| 1984 | Clearcut | 12.9 | .04 |
| | Selection | 5.7 | .01 |
| | Control | 6.9 | .02 |
| 1985 | Clearcut | 11.0 | .03 |
| | Selection | 4.8 | .01 |
| | Control | 6.3 | .01 |

loss from two different harvest methods (Beasley and Granillo, 1985). Selective cutting resulted in sediment yields 2.5 to 20 times less than clearcutting and water yields 1.3 to 2.6 times less than clearcutting. Table 3-3 presents the results of another similar study (Eschner and Larmoyeux, 1963). The study demonstrated decreases in turbidity in water as harvest selectivity, combined with care in planning skid roads, increased. The authors concluded that most damage to water quality can be prevented with careful planning, without greatly restricting harvest management practices. Of course, selective harvesting may result in a need to disturb more acres to yield the same amount of timber, resulting in more miles of road construction, more skidding, more yarding areas, and more overall vehicle activity on soils. This could counteract the positive water quality effects of disturbing less area in each area harvested. Also, while not a water quality concern, research does show that selective harvesting can result in lower quality timber stands. All of these factors should be considered during preharvest planning.

Table 3-3. Effect of four Harvesting Methods on Water Quality (Eschner and Larmoyeux, 1963).

| Watershed Number | Practice | Maximum Turbidity (Turbidity Units) |
|------------------|---------------------|-------------------------------------|
| 1 | Commercial clearcut | 56,000 |
| 2 | Diameter limit | 5,200 |
| 5 | Extensive selection | 210 |
| 3 | Intensive selection | 25 |
| 4 | Control | 15 |

Yarding is an aspect of a harvesting operation where water quality effects can be reduced with thoughtful preharvest planning. Yarding in moderately sloping areas is usually done with ground skidding equipment for uneven-aged systems, and this can cause much more soil disturbance than cable yarding. McMinn (1984) compared a skidder logging system and a cable yarder for their relative effects on soil disturbance (Table 3-4). With the cable yarder, 99 percent of the soil remained undisturbed (the original litter still covered the mineral soil), whereas the amount of soil remaining undisturbed after logging by skidder was only 63 percent. For even-aged systems, cable yarding can be used in sloping areas; cable yarding is not widely used for uneven-aged harvesting because of possible site damage. Skyline cable yarding is performed in a fishbone pattern and can damage a large percentage of the residual stand if used in an uneven-aged system. Cable yarding for uneven-aged stands is also time consuming because the pivot point is moved frequently for removal of specific trees. Clearly, many factors are involved in the selection of harvesting and yarding systems, and many of them must be considered in the context of the individual harvest being done. Water quality considerations should be part of the overall formula.

Table 3-4. Comparison of the Effect of Conventional Logging System and Cable Miniyarder on Soil in Georgia (McMinn, 1984).

| Disturbance Class^a | Cable Skidder | Miniyarder |
|--------------------------------------|----------------------|-------------------|
| Undisturbed | 63% | 99% |
| Soil exposed | 12% | 1% |
| Soil disturbed | 25% | 0% |

^a Undisturbed = original duff or litter still covering the mineral soil.
 Exposed = litter and duff scraped away, exposing mineral soil, but no scarification.
 Disturbed = Mineral soil exposed and scarified or dislocated.

Preharvest planning is an opportunity to consider how harvested areas are to be replanted or regenerated to prevent erosion and effects on waterbodies after the harvest has occurred. At the same time, it is important to consider other activities that have occurred recently, will coincide with the harvesting, or are scheduled to occur in the watershed where harvesting is to take place, as well as the overall soil, habitat, and water quality conditions of the watershed. Other activities within the watershed that can also stress water systems include land use changes from forest to agriculture, residential development or other construction, and applications of pesticides or herbicides. Cumulative effects on soils, water quality, and habitats from other activities and the proposed forest practices can result in excessive erosion and pollutant transport, and detrimental receiving water effects (Sidle, 1989). Cumulative effects are influenced by forest management activities, natural ecosystem processes, and the distribution of other land uses within a watershed. Forestry operations such as timber harvesting, road construction, and chemical use can increase runoff of nonpoint source pollutants and thereby contribute to preexisting impairments to water quality.

A previously-completed cumulative assessment might exist for the area to be harvested, in which case it can be determined whether water quality problems, if any, in the watershed are attributable to the types of pollutants that might be generated by the planned forestry activity. If more pollutants of the same types are likely to be generated

as a result of the harvesting activity, adjustments to the harvest plan or use of management practices beyond those normally used might be necessary. For instance, consider selecting harvest units with low sedimentation risk, such as flat ridges or broad valleys; postponing harvesting until existing erosion sources are stabilized; or selecting limited harvest areas using existing roads. The need for additional measures, as well as the appropriate type and extent, is best considered and addressed during the preharvest planning process.

During preharvest planning, it is also particularly important to plan implementation of management practices to be used to control sediment delivery from sources that are characteristically erosion-prone and lead to water quality impairment at stream crossings, landings, road fills on steep slopes, road drainage structures, and roads located close to streams. Constructing roads through high-erosion-hazard areas can lead to serious water quality degradation and should be avoided when possible. Some geographical areas (e.g., the Pacific coast states) tend to have more serious erosion problems (landslides, major gullies, etc.) after road construction than other areas. Factors such as climate, slope steepness, soil and rock characteristics, and local hydrology influence this potential. High-erosion-hazard areas include badlands, deposits of primarily windblown material (loess), steep and dissected terrain, and areas with existing landslides. A person trained to recognize these characteristics should be involved with preharvest planning. Landslides, gullies, weak soils, unusually high ground water levels, very steep slopes, unvegetated shorelines and streambanks, and major geomorphic changes often indicate hazard locations. Such areas can be identified and avoided during road system planning.

Erosion hazard areas are often mapped by public agencies, and these maps are one tool to use in identifying high-erosion-hazard sites. The U.S. Geological Survey has produced geologic hazard maps for some areas. The USDA Natural Resources Conservation Service (NRCS) and Agricultural Stabilization and Conservation Service (ASCS), as well as State and local agencies, might also have erosion-hazard-area maps.

Benefits of Preharvest Planning

The Virginia Department of Forestry found that preharvest planning is one of the three BMPs that are crucial to water quality protection. The other two are the establishment and use of streamside management areas (SMAs) and properly designed and constructed stream crossings. Although all BMPs are considered to be important, these three were found to be the most important to preventing water quality degradation.

In a study conducted by Black and Clark (no date), sediment concentrations were compared from stream waters in an unlogged watershed, a watershed where a harvesting operation with thorough preharvest planning had been conducted, and a watershed where a harvesting operation with no preharvest planning had been conducted. Sediment concentrations in the water from the unlogged watershed averaged 4 parts per million (ppm), those in the water from the watershed with the planned logging operation averaged 5 ppm, and those from the watershed with the unplanned harvest averaged 31 ppm (Figure 3-2). Preharvest planning in this study took into consideration road siting and construction techniques, landing siting, yarding techniques, and other BMPs intended to minimize erosion and sediment loss.

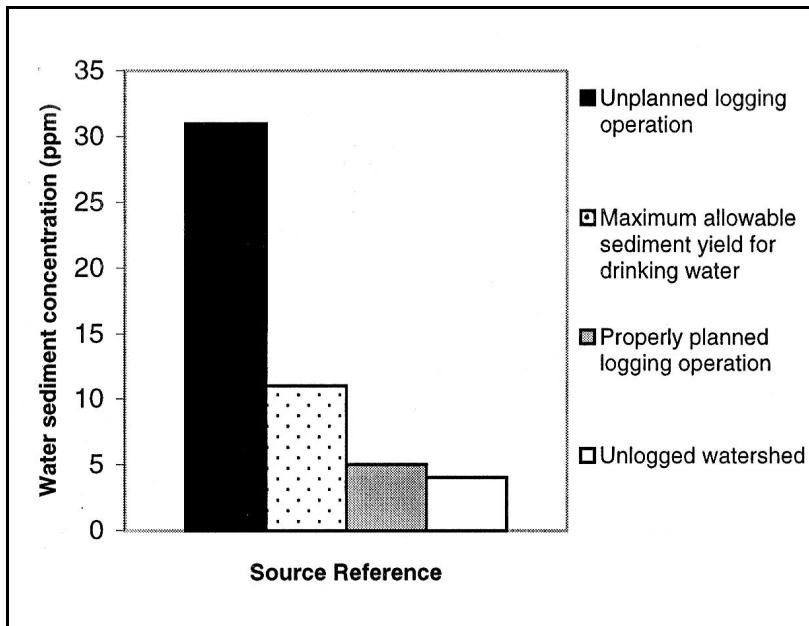


Figure 3-2. Comparison of sediment concentrations in runoff from various forest conditions to drinking water standard (after Black and Clark, nd).

Of course, BMPs are effective only when properly designed, constructed, implemented, and maintained. Too often, BMPs are not installed early enough in the process to effectively control nonpoint source pollution, or they are not maintained properly, which can lead to their failure and to sedimentation or other forms of pollution. In general, poor BMP effectiveness can be attributed to one or more of the following:

- A lack of time or willingness to plan timber harvests carefully before cutting begins.
- A lack of skill in or knowledge of designing effective BMPs.
- A lack of equipment needed to implement effective BMPs.

- The belief that BMPs are not an integral part of the timber harvesting process and can be engineered and fitted to a logging site after timber harvesting has been completed.

Best Management Practices

Harvest Planning Practices

- *Use topographic maps, aerial photographs, soil surveys, geologic maps, and seasonal precipitation information—as slow long duration precipitation can be as limiting as high intensity short duration rainfall—to augment site reconnaissance to lay out and map harvest units. Identify and mark, as appropriate:*
 - Sensitive habitats that need special protection, such as threatened and endangered species nesting areas.
 - Streamside management areas (Figure 3-3).
 - Steep slopes, high-erosion-hazard areas, and landslide-prone areas.
 - Wetlands.
- *In warmer regions, schedule harvest and construction operations during dry periods or seasons. Where weather permits, schedule harvest and construction operations during the winter to take advantage of snow cover and frozen ground conditions.*

- *Consider potential water quality and habitat effects when selecting the silvicultural system as even-aged (clear-cut, seed tree, or shelterwood) or uneven-aged (group or individual selection). The yarding system, site preparation method, and any pesticides that will be used can also be considered during preharvest planning. As part of this practice, consider the potential effects from and extent of roads needed for each silvicultural system.*
- *In high-erosion-hazard areas, trained specialists (geologist, soil scientist, geotechnical engineer, wild land hydrologist) can identify sites that have high risk of landslides or that might become unstable after harvest. These specialists can recommend specific practices to reduce the likelihood of erosion hazards and protect water quality.*

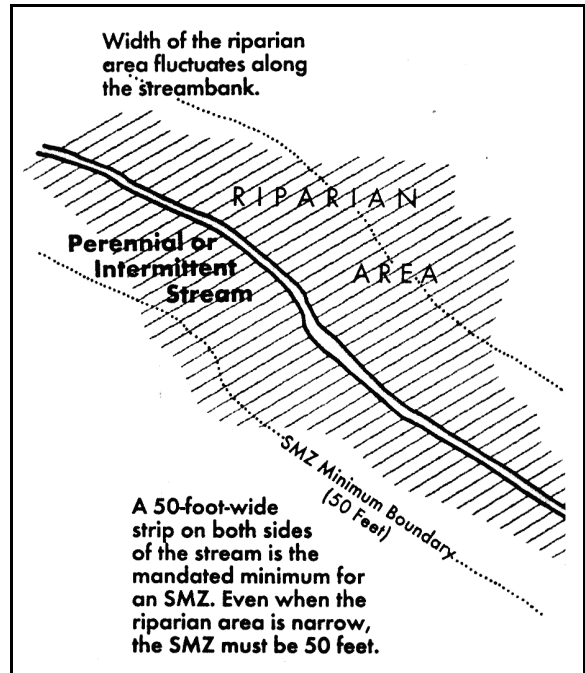


Figure 3-3. A streamside management area (SMA) protects streams from sediment loading, temperature changes, and other effects (Montana State University, 1991).

- *Determine what other harvesting activities, chemical applications, or other potentially polluting activities are scheduled to occur in the watershed and, where appropriate, conduct the harvest at a time and in such a manner as to minimize potential cumulative effects.*

Road System Planning Practices

Road Location Practices

- *Preplan skid trail and landing locations on stable soils and avoid steep gradients, landslide-prone areas, high-erosion-hazard areas, and poor-drainage areas.*
 - Plan to minimize roads, stream crossings, landings, skid trails, and activities on unstable soils and steep slopes.
 - Locate landings outside of SMAs and ephemeral drainage areas.
 - Locate new roads and skid trails outside of SMAs, except where necessary to cross drainages.
 - Locate roads away from stream channels where road fill extends within 50 to 100 horizontal feet of the annual high water level. (Bankfull stage is also used as a reference point for this.)
- *Systematically design transportation systems to minimize total mileage.*

- Compare layouts for roads, skid trails, landings, and yarding plans, and determine which will result in the least soil disturbance and erosion.
 - Locate landings to minimize skid trail and haul road mileage and disturbance of unstable soils.
- ☐ *Identify areas that would need the least modification for use as log landings and use them to reduce the potential for soil disturbance. Avoid using areas, such as ephemeral drainages, that could contribute considerably to nonpoint source pollution if high precipitation occurs during the harvest. Use topographic maps and aerial photographs to locate these areas.*
- ☐ *Plot feasible routes and locations on aerial photographs or topographic maps to assist in the final determination of road locations. Compare the possible road location on-the-ground and proof the layout to ensure that the road follows the contours. Design roads and skid trails to follow the natural topography and contour, minimizing alteration of natural features.*

Proper design can reduce the area of soil exposed by construction activities. Figure 3-4 presents a comparison of road systems. Following the natural topography and contours can reduce the amount of cut and fill needed and consequently reduce both road failure potential and cost. Ridge routes and hillside routes are good locations for ensuring stream protection because they are removed from stream channels and the intervening

undisturbed vegetation acts as a sediment barrier. Wide valley bottoms are good routes if stream crossings are few and roads are located outside SMAs.

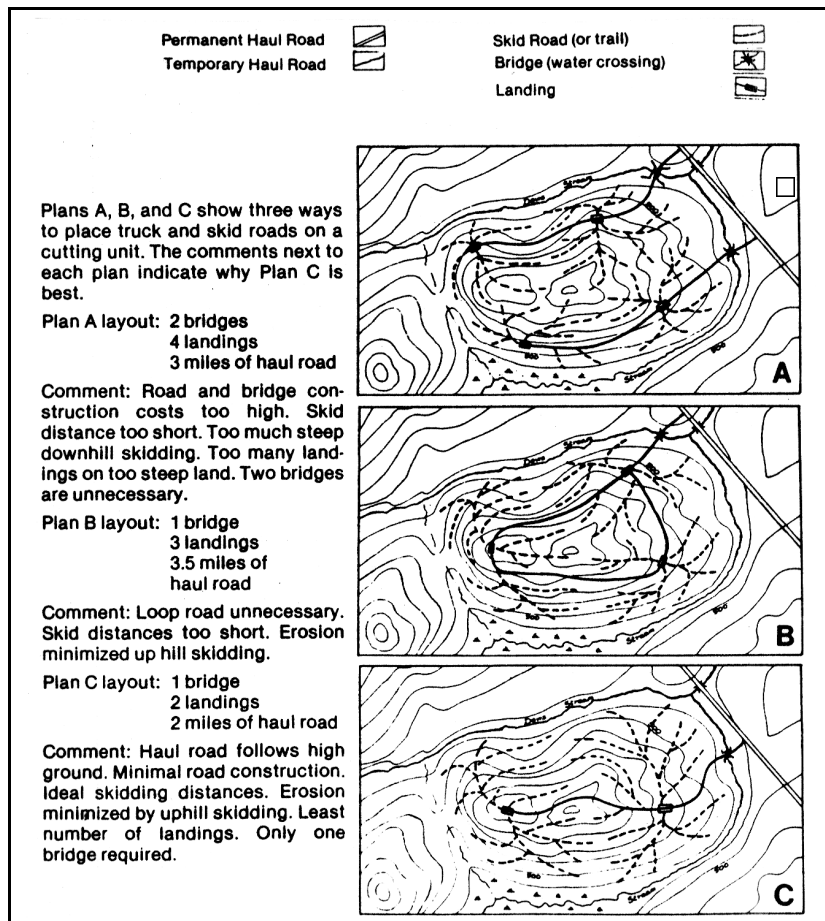


Figure 3-4. An example of laying out sample road systems for comparison purposes (Hynson et al., 1982).

Plan the management of existing and future roads and road systems to minimize environmental problems arising from them.

Roads analysis is an integrated ecological, social, and economic approach to transportation planning addressing both existing and future road systems. The U.S. Forest Service's Roads Analysis procedure, developed by a team of Forest Service scientists and managers, is designed to help national forest managers bring their road systems into balance with current social, economic, and environmental needs. The top priority is to provide road systems that are safe for the public, responsive to public needs, environmentally sound, affordable, and efficient to manage. A roads

analysis provides scientific information used to inform decision makers about effects, consequences, options, priorities, and other factors. This information is essential to plan efficiently and manage the forest transportation crisis. The iterative procedure for conducting the roads analysis consists of six steps aimed at producing needed information and maps (USDA Forest Service, 1999):

- *Step 1: Set up the analysis.* The analysis is designed to produce an overview of the road system. An interdisciplinary team develops a list of information needs and a plan for the analysis.
- *Step 2: Describe the situation.* The interdisciplinary team describes the existing road system in relation to current forest management plans. Products from this step include a map of the existing road system, descriptions of access needs, and information about physical, biological, social, cultural, economic, and political conditions associated with the road system.
- *Step 3: Identify issues.* The interdisciplinary team, in conjunction with the public, identifies important road-related issues and the information needed to address them. The interdisciplinary team also determines data needs associated with analyzing the road system in the context of the important issues, for both existing and future roads. The output from this step includes a summary of key road-related issues, a list of screening questions to evaluate them, a description of the status of relevant available data, and a list of additional data needed to conduct the analysis.
- *Step 4: Assess benefits, problems, and risks.* After identifying the important issues and associated analytical questions, the interdisciplinary team systematically examines the major uses and effects of the road system, including the environmental, social, and economic effects of the existing road system and the values and sensitivities associated with unroaded areas. The output from this step is a synthesis of the benefits, problems, and risks of the current road system and the risks and benefits of building roads into unroaded areas.
- *Step 5: Describe opportunities and set priorities.* The interdisciplinary team identifies management opportunities, establishes priorities, and formulates technical recommendations that respond to the issues and effects. The output from this step includes a map and a descriptive ranking of management options and technical recommendations.
- *Step 6: Report.* The interdisciplinary team then produces a report and maps that portray management opportunities and provide supporting information important for making decisions about the future characteristics of the road system. This information sets the context for the development of proposed actions to improve the road system and for future amendment and revision of forest plans.

- ☐ *Consider using or upgrading existing roads, whenever practical and when less adverse effect would be caused, to minimize the total amount of construction necessary.*

Existing roads should be used wherever possible, unless using such roads would cause more severe erosion problems than building a new alignment elsewhere (Weaver and Hagans, 1994). When access to an existing road is available on the opposite side of the

drainage, consider using it instead of planning and constructing a new road. This practice minimizes the amount of new road construction disturbance. However, avoid using existing or previously-used road locations if they do not meet road standards.

Road Design Practices

- ☐ *In moderately sloping terrain, plan for road grades of less than 10 percent, with an optimal grade of between 3 percent and 5 percent. In steep terrain, short sections of road at steeper grades can be used if the grade is broken at regular intervals. On steep grades, vary road grades frequently to reduce culvert and road drainage ditch flows, road surface erosion, and concentrated culvert discharges.*

Gentle grades are desirable for proper drainage and economical construction. Steeper grades are acceptable for short distances (200-300 feet), but an increased number of drainage structures might be needed above, on, and below the steeper grade to reduce runoff potential and minimize erosion. Heavy traffic on steep grades can result in surface rutting that renders crowning, outsloping, and insloping ineffective. On sloping terrain, no-grade road sections are difficult to drain properly and are best avoided when possible.

- ☐ *Design skid trail grades to be 15 percent or less, with steeper grades only for short distances.*
- ☐ *In designing roads for steep terrain, avoid the use of switchbacks through the use of more favorable locations. Avoid stacking roads above one another in steep terrain by using longer span cable harvest techniques.*
- ☐ *Avoid locating roads where they will need fills on slopes greater than 60 percent. When necessary to construct roads across slopes that exceed the angle of repose, use full-bench construction and/or engineered bin walls or other stabilizing techniques.*
- ☐ *Plan to use full-bench construction and remove fill material to a suitable location where constructing road prisms on side slopes greater than 60 percent.*
- ☐ *Design cut-and-fill slopes to be at stable angles, or less than the normal angle of repose, to minimize erosion and slope failure potential.*

The degree of steepness that can be obtained is determined by the stability of the soil. Figure 3-5 presents recommended stable backslope and fill slope angles for different soil materials.

- Use retaining walls, with properly designed drainage, to reduce and contain excavation and embankment quantities. Vertical banks can be used without retaining walls if the soil is stable and water control structures are adequate.
- Balance excavation and embankments to minimize the need for supplemental building material and to maximize road stability.
- Avoid the use of road fills at drainage crossings as water impoundments unless they have been designed as an earthfill dam (in which case they might be subject to section

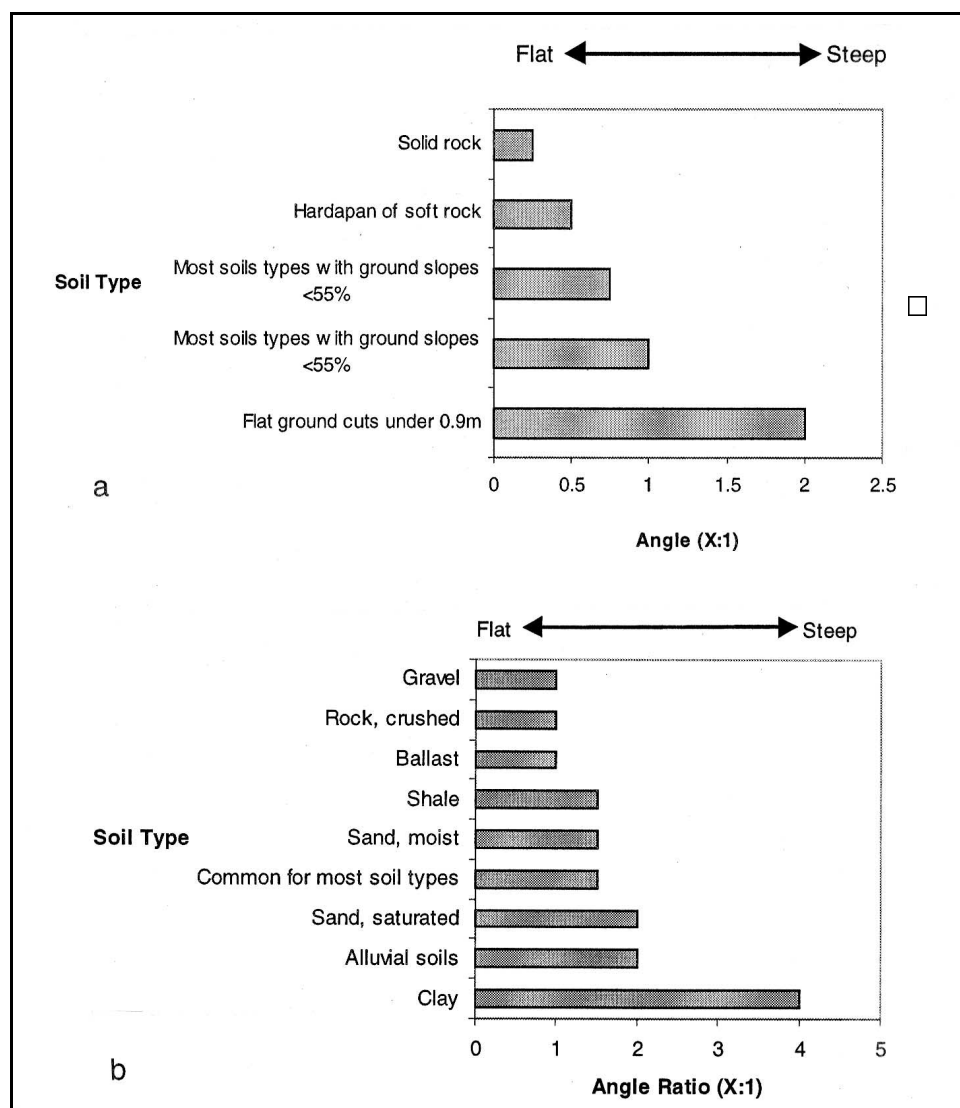


Figure 3-5. Maximum recommended stable angles for (a) backslopes and (b) fill slopes (after Rothwell, 1978).

- *Design roads crossing low-lying areas so that water does not pond on the upslope side of the road.*
 - Use overlay construction techniques with suitable nonhazardous materials for roads crossing muskegs.
 - Provide cross drains at short intervals to ensure free drainage and avoid ponding, especially in sloping areas.
 - Provide adequate cross drainage to maintain natural dispersed hydrologic flows through wet areas.
- *Plan water source developments, used for wetting and compacting roadbeds and surfaces, to prevent channel bank and stream bed effects.*

Design access roads such that they do not provide sediment to the water source.

404 requirements). These earthfill embankments need outlet controls to allow draining prior to runoff periods and a design that permits flood flows to pass.

Try to avoid springs wherever possible. However, where they must be crossed, provide drainage structures for springs that flow to roads and that flow continuously for longer than 1 month, rather than allowing road ditches to carry the flow to a drainage culvert.

Avoiding springs will limit disruptions to the natural hydrology of an area and limit the extent to which roads can become integrated into an area's drainage system. Unmanaged springs can compromise sections of roads and contribute to erosion and sedimentation.

Road Surfacing Practices

- *Plan to surface most forest roads, and select a road surface material suitable for the intended road use and likelihood of water quality effects.*

The volume and composition of traffic, the desired service life, and the stability and strength of the road foundation (subgrade) material will determine the type of road surfacing needed. Roads that are closer to streams or other surface waters should be considered for a durable, non-erosive surface.

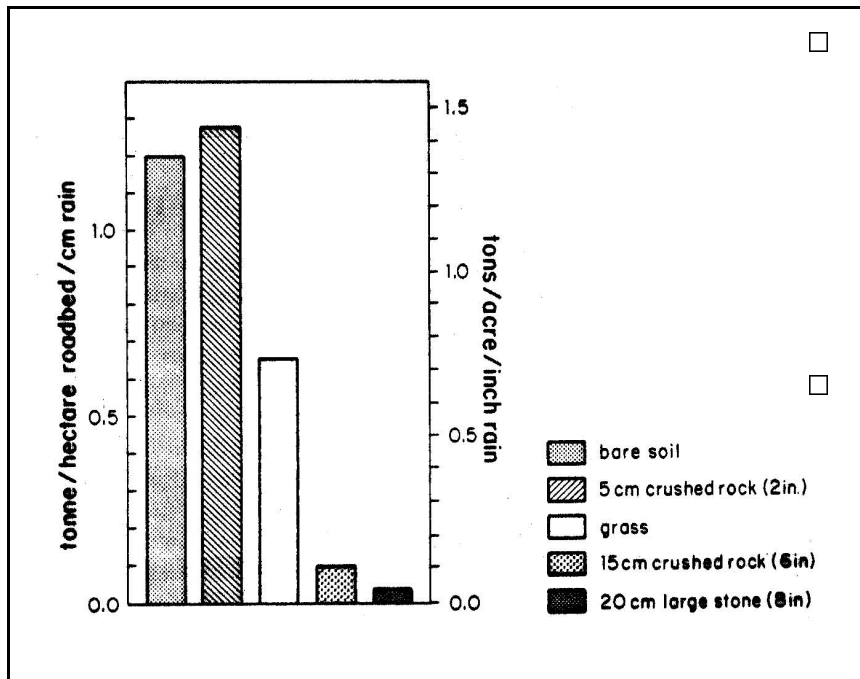


Figure 3-6. Soil loss rate for roadbeds with five surfacing treatments. Roads constructed of sandy loam saprolite (Swift, 1988).

Design roads with a surface of gravel, grass, wood chips, or crushed rocks where grades increase the potential for surface erosion.

Figure 3-6 compares roadbed erosion rates for different surfacing materials.

Select an appropriately sized aggregate, appropriate percentage of fines, and suitable particle hardness to protect road surfaces from rutting and erosion under heavy truck traffic during wet periods. Do not use aggregate containing hazardous materials or high-sulfide ores.

Road Stream Crossing Practices

- *Lay out roads, skid trails, and harvest units to minimize the number of stream crossings.*
- *Design and site stream crossings to cross drainages perpendicular to the streamflow. Design road segments with water turn-outs and broad-based dips to minimize runoff directly entering the stream at the crossing.*
- *Locate stream crossings to avoid channel changes and minimize the amount of excavation or fill needed at the crossing. Apply the following criteria to determine the locations of stream crossings:*
 - Construct crossings at locations where the streambed has a straight and uniform profile above, at, and below the crossing.
 - Locate the crossing so the stream and road alignment are straight in all four directions.
 - Cross where the stream is relatively narrow with low banks and firm, rocky soil.

- Avoid deeply cut streambanks and soft, muddy soil.
- *Choose stream-crossing structures (bridges, culverts, or fords) with the structural capacity to safely handle expected vehicle loads with the least disturbance to the watercourse. The following factors will determine which stream-crossing structure is optimal: stream size, storm frequency and flow rates, watershed size, presence of intermittent and ephemeral drainages, intensity of use (permanent or temporary), season of use, water quality, habitat value, and requirement for fish passage.*
- *Design culverts and bridges for minimal effect on water quality. Install culverts of a size that is appropriate to pass a design storm. Opening size varies depending on climate, the drainage area upstream of where the stream-crossing structure is to be placed, and the likelihood of plugging with debris.*

Consider the following guidelines for culvert sizing, but consult the state forestry agency and local hydrologists: a 50-year design storm for small diameter culverts and a 100-year design storm for large diameter culverts and bridges. Bridges or arch culverts, which retain the natural stream bottom and slope, are preferred over pipe culverts for streams used for fish migrating or spawning areas (Figures 3-7 and 3-8). Fish passage can be provided in streams that have wide ranges of flow by providing multiple culverts (Figure 3-9).

- *The use of fords is best limited to areas where the stream bed has a firm rock or gravel bottom (or where the bottom has been armored with stable material), where the approaches are both low and stable enough to support traffic, where fish are not present during low flow, and where the water depth is no more than 3 feet.*
- *Design small stream crossings on temporary roads using temporary bridges.*

Temporary bridges usually consist of logs bound together and suspended above the stream, with no part in contact with the stream itself. This prevents streambank erosion, disturbance of stream bottoms, and excessive turbidity. Provide additional capacity to accommodate debris loading that might lodge in the structure opening and reduce its capacity.

Scheduling Practices

- *Plan road construction or improvement to allow sufficient time afterward for disturbed soil and fill material to stabilize prior to use of the road.*

Compact and stabilize roads prior to use. This reduces the amount of maintenance needed during and after harvesting activities.

- *To minimize soil disturbance and road damage, plan to suspend operations when soils are highly saturated. This will reduce sediment runoff potential and creation of ruts in the haul road, landings, skid trails, and loading areas, which in turn will prevent possible damage to vehicles. Damage to forested slopes can also be minimized by not operating logging equipment when soils are wet, during wet weather, or when the ground is thawing.*

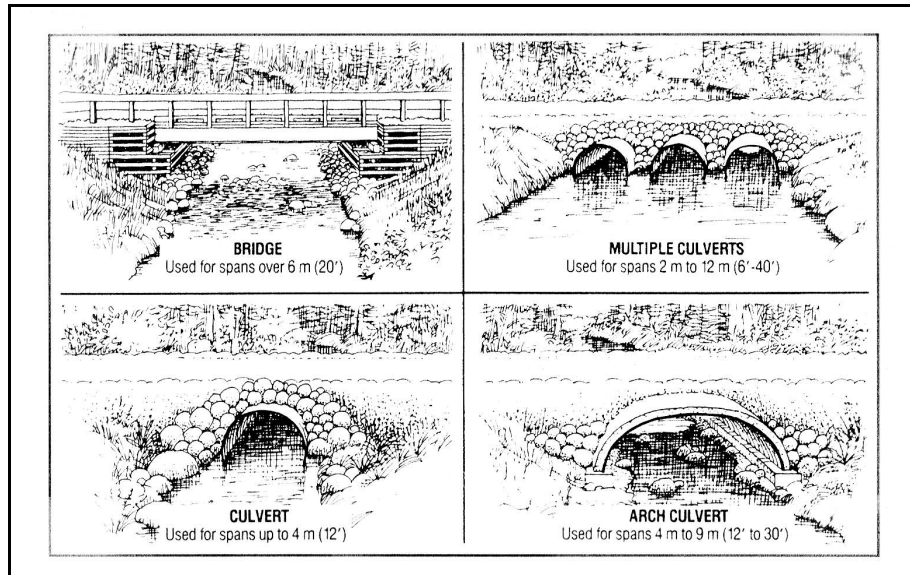


Figure 3-7. Alternative water crossing structures (Ontario Ministry of Natural Resources, 1988).

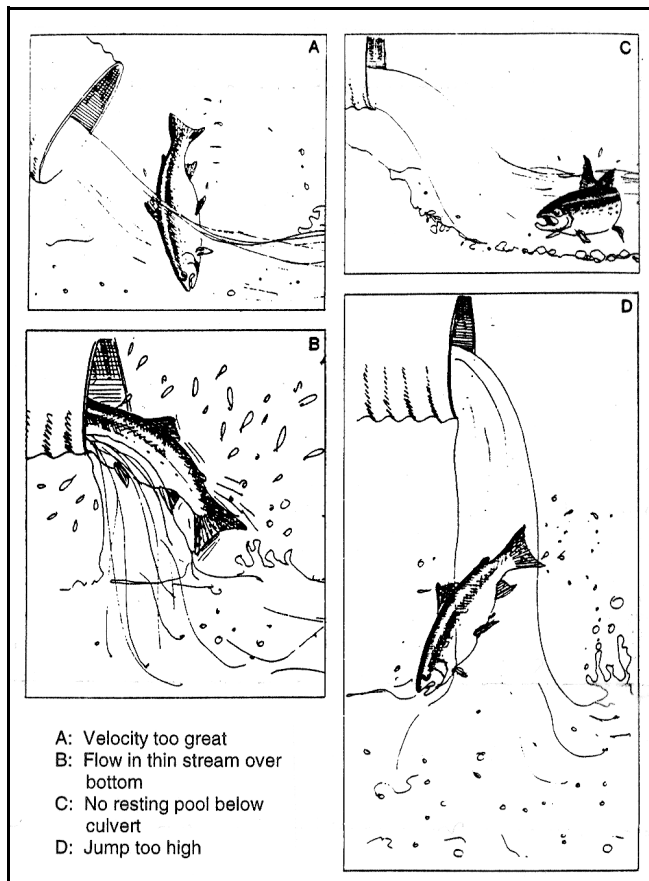


Figure 3-8. Culvert conditions that block fish passage (Yee and Roelofs, 1980).

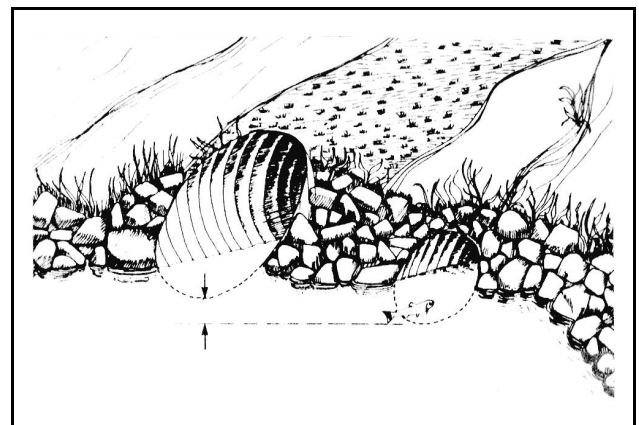


Figure 3-9. Multiple culverts for fish passage in streams that have a wide range of flows (Hynson et al., 1982).

Preharvest Notification Practices

- *Encourage timberland owners and harvesters to submit a preharvest plan to the state for review prior to performing any road work or harvesting.*

States are encouraged to adopt notification mechanisms for harvest planning that integrate and avoid duplicating existing requirements or recommendations for notification, including severance taxes, stream crossing permits, erosion control permits, labor permits, forest practice acts, plans, and so forth. For example, states might recommend that a preharvest plan be submitted by the landowner to a single state or local office. The appropriate state agency might encourage forest landowners to develop a preharvest plan. The plan would address the components of this management measure, including the area to be harvested, any forest roads to be constructed, and the timing of the activity.

Many states currently use some process to ensure implementation of management practices. These processes are typically related to the planning phase of forestry operations and commonly involve some type of notification process. Some states have one or more processes in place that serve as notification mechanisms used to ensure implementation. These state processes are usually associated with forest practices acts, erosion control acts, state dredge and fill or CWA section 404 requirements, timber tax requirements, or state and federal incentive and cost share programs. Some state education and training programs are discussed in Section 2.

It is suggested that notification be encouraged prior to:

- Timber harvesting or commercial timber cutting.
- Road construction or road improvement.
- Stream crossing construction or any work within 50 feet of a watercourse or waterbody.
- Reforestation.
- Pesticide, herbicide, or fertilizer applications.
- Any work in a wetland.
- Conversion of forestland to a non-forest use.

3B: Streamside Management Areas

Management Measure for Streamside Management Areas:

Establish and maintain a streamside management area along surface waters, which is sufficiently wide and which includes a sufficient number of canopy species to buffer against detrimental changes in the temperature regime of the waterbody, to provide bank stability, and to withstand wind damage. Manage the SMA in such a way as to protect against soil disturbance in the SMA and delivery to the stream of sediments and nutrients generated by forestry activities, including harvesting. Manage the SMA canopy species to provide a sustainable source of large woody debris needed for in-stream channel structure and aquatic species habitat.

Management Measure Description

Riparian vegetation is widely recognized to be highly beneficial to water quality and aquatic habitat. Vegetation in riparian areas reduces runoff and traps sediments generated from upslope activities and reduces nutrients in runoff before it reaches surface waters (Figure 3-10). Canopy species provide shading to surface waters, which moderates water temperature and provides the detritus that serves as an energy source for stream ecosystems. Trees in the riparian areas also provide a source of large woody debris to surface waters. Riparian areas provide important habitat for aquatic organisms and terrestrial species while preventing excessive logging-generated slash and debris from reaching waterbodies.

Streamside management areas (SMAs), also commonly referred to as streamside management zones or riparian management areas or zones, are areas of riparian vegetation along streams that receive special management attention because of their value in protecting water quality and habitat. SMAs need to be of sufficient width to prevent delivery of sediments and nutrients generated from forestry activities (harvest, site preparation, or roads) in upland areas to the waterbody being protected (Figure 3-11). SMAs generally have a minimum width of 35-50 feet to be effective, though they might be narrower or wider depending on site-specific factors. Factors to consider in determining SMA width include slope, soil type, vegetation type, precipitation, canopy density, class of waterbody, and intensity of management (Figure 3-12). Areas such as intermittent channels, ephemeral channels, and depressions need to be given special consideration when determining SMA boundaries. Channels should be disturbed as little as possible to maximize the effectiveness of an SMA, as disturbance in and adjacent to a SMA can contribute considerably to runoff volumes. SMAs also need to be able to withstand wind damage or blowdown. For example, a single rank of canopy trees is not likely to withstand blowdown and maintain the functions of an SMA.

Table 3-5 presents North Carolina's recommendations for SMA widths for various types of waterbodies dependent on adjacent upland slope. Maine's recommended filter strip widths are dependent on the land slope between the road and the waterbody (Table 3-6). SMA widths might vary along a stream's course and on opposite sides of the same

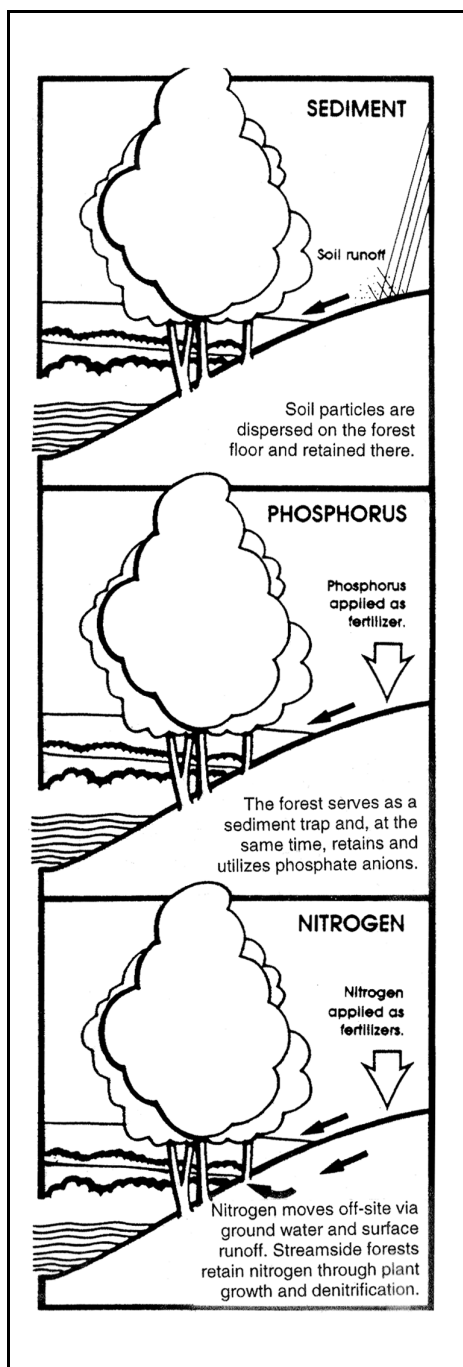


Figure 3-10. Streamside management area pollutant removal processes (Kundt and Hall, 1988).

preferably a quantity of trees that provide a minimum of 50 percent of the summer midday shade. Shade cover is preferably left distributed evenly within the SMA. If a threat of blowdown exists, leave trees may be clumped and clustered as long as sufficient shade at the reach scale is provided.

Hall and others (1987) studied the effectiveness of SMAs in protecting streams from temperature increases, large increases in sediment load, and reduced dissolved oxygen (Table 3-7). Hartman and others (1987) compared the physical changes associated with

stream. SMA width is measured along the ground from the streambank on each side of the stream and not from the centerline of the watercourse (Georgia Forestry Commission, 1999).

A sufficient number of large trees in an SMA provide for bank stability and a sustainable source of large woody debris. Large woody debris consists of naturally occurring dead and downed woody materials, not to be confused with logging slash or debris. Trees to be maintained or managed in the SMA can provide large woody debris to the stream at a rate that maintains beneficial uses associated with fish habitat and stream structure at the site and downstream and that is sustainable over a time period long enough to allow the tree species in the SMA to grow to the size needed to provide large woody debris.

A sufficient number of canopy species are maintained in an SMA to provide shading to the stream water surface needed to prevent changes in the temperature regime of the waterbody and to prevent harmful temperature- or sunlight-related effects on the aquatic biota. If the existing shading conditions for the waterbody prior to activity are known to be less than optimal for the stream, SMAs can be managed to increase shading of the waterbody.

To preserve SMA integrity for water quality protection, some states limit the type of harvesting, timing of operations, amount harvested, or reforestation methods used in them. SMAs are managed to use only harvest and silvicultural methods that prevent soil disturbance in the SMA. Additional operational considerations for SMAs are addressed in subsequent management measures. Practices for SMA applications to wetlands are described in the Wetlands Forest Management Measure (Subsection 3J).

Benefits of Streamside Management Areas

The effectiveness of SMAs in regulating water temperature depends on the interrelationship between vegetative and stream characteristics. Specifying leave tree and stream shade quantities is an effective way to prevent detrimental temperature changes. An example of a leave tree specification might be *Leave trees that provide midsummer and midday shade to the water surface, and*

logging using three streamside treatments—leaving a variable-width strip of vegetation along a stream (least intensive); clear cutting to the margin of a stream, but with virtually no instream disturbance (intensive); and clearcutting to the streambank with some yarding near the stream and pulling merchantable timber from the stream (most

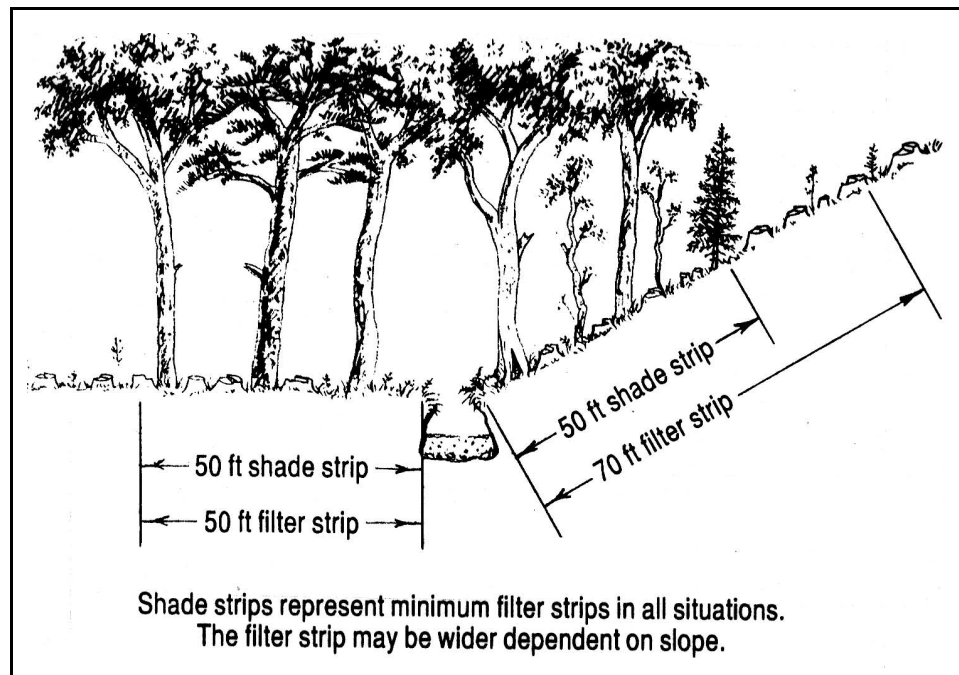


Figure 3-11. Streamside management area width depends on slope and other factors (Minnesota DNR, 1995).

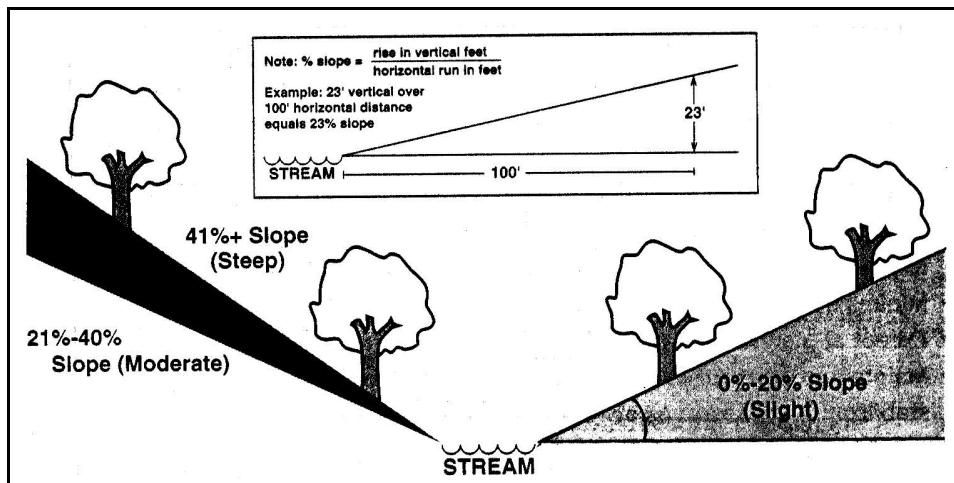


Figure 3-12. Calculation of slope is an important step in determining SMA width (Georgia Forestry Commission, 1999).

Table 3-5. Recommended Minimum SMZ Widths (North Carolina Division of Forest Resources, 1989).

| Type of Stream or Waterbody | Percent Slope of Adjacent Lands | | | | |
|---|---------------------------------|------|-------|-------|-----|
| | 0-5 | 6-10 | 11-20 | 21-45 | 46+ |
| | SMZ Width Each Side (feet) | | | | |
| Intermittent | 50 | 50 | 50 | 50 | 50 |
| Perennial | 50 | 50 | 50 | 50 | 50 |
| Perennial Trout Waters | 50 | 66 | 75 | 100 | 125 |
| Public Water Supplies (Streams and Reservoirs) | 50 | 100 | 150 | 150 | 200 |

Table 3-6. Recommendations for Filter Strip Widths (Maine Forest Service, 1991).

| Slope of Land (%) | Width of Strip (ft along ground) |
|-------------------|----------------------------------|
| 0 | 25 |
| 10 | 45 |
| 20 | 65 |
| 30 | 85 |
| 40 | 105 |
| 50 | 125 |
| 60 | 145 |
| 70 | 165 |

Table 3-7. Comparison of Effects of Two Methods of Harvesting on Water Quality (Oregon) (Hall et al., 1987).

| Watershed | Method | Streamflow | Water Temperature | Sediment | Dissolved Oxygen |
|---------------|--|--------------------------|--|--|--|
| Deer Creek | Patch cut with buffer strips (750 acres) | No increase in peak flow | No change | Increases for one year due to periodic road failure | No change |
| Needle Branch | Clearcut with no stream protection (175 acres) | Small increases | Large changes, daily maximum increase by 30°F, returning to pre-log temp. within 7 years | Five-fold increase during first winter, returning to near normal the fourth year after harvest | Reduced by logging slash to near zero in some reaches; returned to normal when slash removed |

intensive). They performed their study to observe the effect of different SMAs on the supply of woody debris, which is essential to fish populations and channel structure. The volume and stability of large woody debris decreased immediately in the most intensive treatment area, decreased a few years after logging in the careful logging area, and remained stable where streamside trees and other vegetation remained.

The costs associated with SMAs vary according to site conditions. SMAs can be more difficult to lay out on rough terrain or along a stream or river that meanders a lot due to the need to adjust the SMA width appropriately. Also, harvesters or landowners take into account the quantity of merchantable timber left unharvested because of SMA restrictions. No single SMA width or layout is preferable for all sites in terms of cost. Dykstra and Froelich (1976a) concluded in one study that a 55-foot buffer strip was the least costly on a million-board-foot (mbf) basis, but they cautioned that cost is not the only factor to consider when deciding what type of stream protection to use (Table 3-8).

Table 3-8. Average Estimated Logging and Stream Protection Costs per MBF^a (Oregon) (Dykstra and Froehlich, 1976a).

| Cutting Practice | Total Cost | | Volume Foregone |
|---|------------|-----------------|-----------------|
| | Average | Range | |
| Conventional felling | \$70.98 | \$62.74 - 85.74 | None |
| Cable-assisted directional felling (1.43% breakage saved within 200-foot stream) | \$74.62 | \$61.19 - 89.49 | -- |
| Cable-assisted felling (10% breakage saved) | \$70.59 | \$56.00 - 85.42 | -- |
| Buffer strip (55 feet wide) | \$66.86 | \$56.84 - 79.55 | 0 - 6 percent |
| Buffer strip (150 feet wide) | \$77.78 | \$69.70 - 86.74 | 6 - 17 percent |

There are several research papers that focus on the costs of SMA implementation. Lickwar (1989) examined the costs of SMAs as determined by varying slope steepness (Table 3-9) in different regions in the Southeast and compared them to road construction and revegetation practice costs. He found that SMAs are the least expensive practice, in general, and that their cost is approximately the same regardless of slope. The costs associated with use of alternative buffer and filter strips were also analyzed in an Oregon study (Olsen, 1987) (Table 3-10). In that study, increasing the SMA width from 35 feet on each side of a stream to 50 feet reduced the value per acre by \$75 (discounted cost) to \$103 (undiscounted cost), or an approximate 2 percent increase in harvesting cost per acre (from \$3,163 discounted to \$5,163 undiscounted). Doubling the SMA width from 35 to 70 feet on each side of a stream reduced the dollar value per acre by approximately 3 times, adding approximately 8 percent to the discounted harvesting costs.

Lynch and others (1985) studied the effectiveness of SMAs in controlling suspended sediment and turbidity levels (Table 3-11). A combination of practices were applied, including SMAs and prohibitions on skidding, slash disposal, and roads located in or near streams. Average storm water-suspended sediment and turbidity levels in the area without

Table 3-9. Cost Estimates (and Cost as a Percent of Gross Revenues) for Streamside Management Areas (Lickwar, 1989).

| Practice Component | Steep Sites ^a | Moderate Sites ^b | Flat Sites ^c |
|-----------------------------|--------------------------|-----------------------------|-------------------------|
| Streamside Management Zones | \$2,958 (0.52%) | \$3,441 (0.51%) | \$3,363 (0.26%) |

these practices were very high compared to those of the control and SMA/BMP sites. Table 3-12 presents data on how effective different cutting practices and buffer strips are in preventing debris from entering the stream channel (Froehlich, 1973).

According to the Vermont Agency of Natural Resources, adequately sized SMAs are the best means to protect water quality (VANR, 1998). The agency conducted habitat assessments and bioassessments on stream segments above and below harvest sites and before and after harvesting and determined that SMAs are particularly important for protecting small headwater streams and ephemeral stream channels. The Virginia Department of Forestry also monitored BMP implementation and effectiveness and determined that although improvement was needed in meeting minimum standards of implementation, properly implemented SMAs (together with stream crossings and preharvest plans) are crucial to protecting water quality.

The Oregon Department of Forestry similarly found that application of a riparian rule (passed in 1987) results in stream protection that generally maintains preoperation vegetative conditions.

Where SMAs were found to be ineffective or less effective than possible, the Virginia Department of Forestry discovered that in some cases this was the result of careless timber harvesting in the SMAs, a lack of adequately sized SMAs on adjacent intermittent streams, or gaps in SMAs caused by cutting in them.

Of course, BMPs are effective only when properly designed and constructed. In general, poor BMP effectiveness can be attributed to one or more of the following:

- A lack of time or willingness to plan timber harvests carefully before cutting begins.
- A lack of skill in or knowledge of designing effective BMPs.
- A lack of equipment needed to implement BMPs effectively.
- The belief that BMPs are not an integral part of the timber harvesting process and can be engineered and fitted to a logging site after timber harvesting has been completed.
- A lack of timely implementation and maintenance of BMPs.

Table 3-10. Cost Effects of Three Alternative Buffer Strips (Oregon): Case Study Results with 640-acre Base (36 mbf/acre) (Olsen, 1987).

| | Scenario | | |
|--|------------|------------|------------|
| | I | II | III |
| Average buffer width (feet on each side) | 35 | 50 | 70 |
| Percent conifers removed | 100 | 60 | 25 |
| Percent reclassified Class II streams ^b | 0 | 20 | 80 |
| Harvesting restrictions | Current | New | New |
| <u>Road Construction</u> | | | |
| New miles | 2.09 | 2.14 | 3.06 |
| Road and landing acres | 10.9 | 11.1 | 15.9 |
| Cost total (1000's) | \$96.00 | \$102.00 | \$197.00 |
| Cost/acre | \$149.00 | \$160.00 | \$307.00 |
| <u>Harvesting Activities^c</u> | | | |
| mmbf harvested | 22.681 | 22.265 | 20.277 |
| Acres harvested | 638.3 | 635.5 | 633.1 |
| Cost total (1000's) | \$3,104.00 | \$3,101.00 | \$2,842.00 |
| Cost/acre | \$4,841.00 | \$4,835.00 | \$4,432.00 |
| Cost/mbf | \$136.87 | \$139.26 | \$140.17 |
| <u>Inaccessible Area and Volume</u> | | | |
| Percent area in buffers | 1.3 | 3.9 | 14.0 |
| mmbf left in buffers | 0.000 | 0.313 | 2.214 |
| Acres unloggable | 1.44 | 4.32 | 6.72 |
| mmbf lost to roads and landings | 0.202 | 0.205 | 0.295 |
| <u>Undiscounted Costs (1000's)</u> | | | |
| Road cost | \$96.00 | \$102.00 | \$197.00 |
| Harvesting cost | \$3,104.00 | \$3,101.00 | \$2,842.00 |
| Value of volume foregone ^d | \$38.00 | \$101.00 | \$413.00 |
| Total | \$3,238.00 | \$3,304.00 | \$3,451.00 |
| Cost/acre | \$5,060.00 | \$5,163.00 | \$5,393.00 |
| Reduced dollar value/acre | — | \$103.00 | \$323.00 |
| <u>Discounted Costs</u> | | | |
| Cost with 4% discount rate (1000's) | \$2,023.00 | \$2,071.00 | \$2,195.00 |
| Cost/acre | \$3,162.00 | \$3,237.00 | \$3,431.00 |
| Reduced value/acre | — | \$75.00 | \$269.00 |

mmbf = million board feet; mbf = thousand board feet

^a 1986 dollars.^b Generally, only Class I streams are buffered.^c Includes felling, landing construction and setup, yarding, loading, and hauling.^d Volume foregone x net revenue (\$150/mbf).

Table 3-11. Storm Water Suspended Sediment Delivery for Treatments (Pennsylvania) (Lynch et al., 1985).

| Water Year and Treatment | Annual Average Suspended Sediment in mg/L (Range) |
|---|--|
| 1977 | |
| Forested control | 1.7(0.2 - 8.6) |
| Clear-cut-herbicide | 10.4(2.3 - 30.5) |
| Commercial clear-cut with BMPs ^a | 5.9(0.3 - 20.9) |
| 1978 | |
| Forested control | 5.1(0.3 - 33.5) |
| Clear-cut-herbicide | — ^b (1.8 - 38.0) |
| Commercial clear-cut with BMPs ^a | 9.3(0.2 - 76.0) |

Table 3-12. Average Changes in Total Coarse and Fine Debris of a Stream Channel After Harvesting (Oregon) (Froehlich, 1973).

| | Natural Debris | Material Added in Felling | % Increase |
|---|------------------------------------|------------------------------|---------------|
| Cutting Practice | (tons per hundred feet of channel) | | |
| Conventional tree-felling | 8.1 | 47 | 570 |
| Cable-assisted directional felling | 16 | 14 | 112 |
| Conventional tree-felling with buffer strip ^a | 12 | 1.3 | 14 |

^a Buffer strips ranged from 20 to 130 feet wide for different channel segments.

Best Management Practices

- ☐ *Minimize disturbances that would expose the mineral soil of the SMA forest floor. Do not operate skidders or other heavy machinery in the SMA.*
- ☐ *Locate all landings, portable sawmills, and roads outside the SMA.*
- ☐ *Restrict mechanical site preparation in the SMA, and encourage natural revegetation, seeding, and hand planting.*
- ☐ *Limit pesticide and fertilizer usage in the SMA. Establish buffers for pesticide application for all flowing streams.*
- ☐ *Directionally fell trees away from streams to prevent logging slash and organic debris from entering the waterbody. Remove slash and debris unless consultation with a fisheries biologist indicates that it should be left in the stream for large woody debris.*

- *Apply harvesting restrictions in the SMA to maintain its integrity.*

Vegetation, including trees, should be left in the SMA to achieve the desired objective for the area, such as maintain shading and bank stability and to provide adequate woody debris to create habitat diversity and provide nutrients to surface waters. This provision for leaving residual trees might be specified in various ways. For example, the Maine Forestry Service specifies that no more than 40 percent of the total volume of timber 6 inches diameter breast height (DBH) and greater be removed in a 10-year period, and that the trees removed be reasonably distributed within the SMA. Florida recommends leaving a volume equal to or exceeding one-half the volume of a fully stocked stand. The number of residual trees varies inversely with their average diameter. A shading specification that is independent of the volume of timber might be necessary for streams where temperature changes could alter aquatic habitat.

3C: Road Construction/Reconstruction

Management Measure for Road Construction/Reconstruction

- (1) Follow preharvest planning (as described under the Management Measure for Preharvest Planning) when constructing or reconstructing the roadway.
- (2) Follow designs planned under the Management Measure for Preharvest Planning for road surfacing and shaping.
- (3) Install road drainage structures according to designs planned under the Management Measure for Preharvest Planning and regional storm return period and installation specifications. Match these drainage structures with terrain features and with road surface and prism designs.
- (4) Guard against the production of sediment when installing stream crossings.
- (5) Protect surface waters from slash and debris material from roadway clearing.
- (6) Use straw bales, silt fences, mulching, or other favorable practices on disturbed soils on unstable cuts, fills, etc.
- (7) Avoid constructing new roads in streamside management areas to the extent practicable.

Management Measure Description

Road construction is one of the largest potential sources of silviculture-produced sediment (Megahan, 1980), and road and drainage crossing construction practices that minimize sediment delivery to surface waters are essential for protecting water quality. Water quality degradation resulting from forest roads is mostly attributable to sediment loss during road construction, erosion that occurs within a few years after soil disturbance from road construction, and during periods of heavy road use. An early study of erosion from road construction concluded that the amount of sediment produced by road construction is directly related to the percent of area occupied by roads, whether a road is given a protective surface, and the amount of protection provided to loose soils on back slopes and fill slopes (King, 1984) (Table 3-13). Best management practices related to these aspects of road construction, and for stream crossing construction, are the subject of this management measure. Erosion and water quality degradation are also problems associated with older, unmaintained roads, and BMPs for road maintenance are the subject of the next management measure.

General Road Construction Considerations

Road design and construction that are tailored to the topography and soils and that take into consideration the overall drainage pattern in the watershed where the road is being constructed can prevent road-related water quality problems. Lack of adequate consideration of watershed and site characteristics, road system design, and construction techniques appropriate to site circumstances can result in mass soil movements, extensive surface erosion, and severe sedimentation in nearby waterbodies. The effect that a forest road network has on stream networks largely depends on the extent to which the road and stream networks are interconnected. Road networks can be hydrologically

Table 3-13. Effects of Several Road Construction Treatments on Sediment Yield in Idaho (King, 1984).

| Watershed Area (acres) | Area in Roads (percent) | Treatment | Increase of Annual Sediment Yield ^a (percent) |
|------------------------|-------------------------|--|--|
| 207 | 3.9 | Unsurfaced roads; Untreated cut slope; Untreated fill slope | 156 |
| 161 | 2.6 | Unsurfaced roads; Untreated cut slope dry seeded | 130 |
| 364 | 3.7 | Surfaced roads; Cut and fill slopes straw mulched and seeded | 93 |
| 154 | 1.8 | Surfaced roads; Filter windrowed; Cut and fill slopes straw mulched and seeded | 53 |
| 70 | 3.0 | Surfaced roads; Filter windrowed; Cut and fill slopes hydro-mulched and seeded | 25 |
| 213 | 4.3 | Surfaced roads; Filter windrowed; Cut and fill slopes hydro-mulched and seeded | 19 |

^a Measured in debris basins.

connected to stream networks where road surface runoff is delivered directly to stream channels at stream crossings or via ditches or gullies that direct flow off of the road and then to a stream, and where road cuts transform subsurface flow into surface flow in road ditches or on road surfaces that delivers sediment and water to streams much more quickly than without a road present and increases the risk of mass wasting (Jones and Grant, 1996; Montgomery, 1994; Wemple et al., 1996). The combined effects of these drainage network connections are increased sedimentation and peak flows that are higher and arrive more quickly after storms. This in turn can lead to increased instream erosion and stream channel changes. This effect is strongest in small watersheds (Jones et al., In press).

Site characteristics are first considered during preharvest planning, and it is important to review the harvesting plan at the harvest site before construction begins to verify assumptions made during planning. On-site verification of information from topographic maps, soil maps, and aerial photos is necessary to ensure that locations where roads are to be cut into slopes or built on steep slopes or where skid trails, landings, and equipment maintenance areas are to be located are appropriate to the use. If an on-site visit indicates that changes to road, skid trail, or landing locations can reduce the risk of erosion, the project manager can make these changes prior to construction, and in some cases as the project progresses.

Road drainage features tailored to the site and its conditions prevent water from pooling or collecting on road surfaces and thereby prevent saturation of the road surface, which can lead to rutting, road slumping, and channel washout. It is especially important to ensure that road drainage structures are well constructed and designed for use during logging operations because the heavy vehicle use during harvesting creates a high potential for the contribution of large quantities of sediment to runoff.

Some roads are temporary or seasonal-use roads, and their construction should not generally involve the high level of disturbance generated by the construction of permanent, high-standard roads. However, temporary or low-standard roads still need to be constructed and maintained to prevent erosion and sedimentation, and many of the BMPs discussed for this management measure are applicable to temporary road construction.

In a study in three headwater watersheds in the mountains of central Idaho, 70 percent of sediment deposition from roads constructed on the watersheds, where the slope ranged from 15 to 40 percent, occurred during the first year after construction, and one-fourth of this deposition occurred during road construction (Ketcheson and Megahan, 1996). In this study, sediment usually traveled less than 100 meters (m) from its source. The distance that sediment traveled varied depending on its source: the distance traveled from fills, rock drains, berm drains, and landings was between 4 m and 20 m, while that from cross drains was 50 m. The maximum travel distance from some cross drains was more than 250 m. Cross drains have a larger source area from which runoff is collected, including the road prism and upslope watershed area, and this accounted for more sediment being deposited than from all other sources combined. These findings highlight the importance of road placement, design, and construction in relation to watercourse location and the installation of BMPs to control runoff sedimentation from roads.

Based on the findings of studies such as this, it is clear that erosion control practices need to be applied while a road is being constructed, when soils are most susceptible to erosion, to minimize soil loss to waterbodies. Since sedimentation from roads often does not occur incrementally and continuously, but in pulses during large rainstorms, it is important that road, drainage structure, and stream crossing design take into consideration a sufficiently large design storm that has a good chance of occurring during the life of the project. Such a storm might be the 10-year, 25-year, 50-year, or even 100-year, 12- to 24-hour return period storm. Sedimentation cannot be completely prevented during or after road construction, but the process is certainly exacerbated if the road construction and design are inappropriate for the site conditions or if the road drainage or stream crossing structures are insufficient.

Several common practices minimize erosion during road construction. In general, it is recommended that forest roads be constructed as a single lane for minimum width and outsloped with minimal cut-and-fill, where conditions are suitable (Weaver and Hagans, 1984). These roads should cause the least disturbance and have lower maintenance costs. Figure 3-13 illustrates various erosion and sediment control practices. Aspects of road construction addressed by the BMPs discussed under this management measure are introduced below. Further information is provided in the discussions of the individual BMPs.

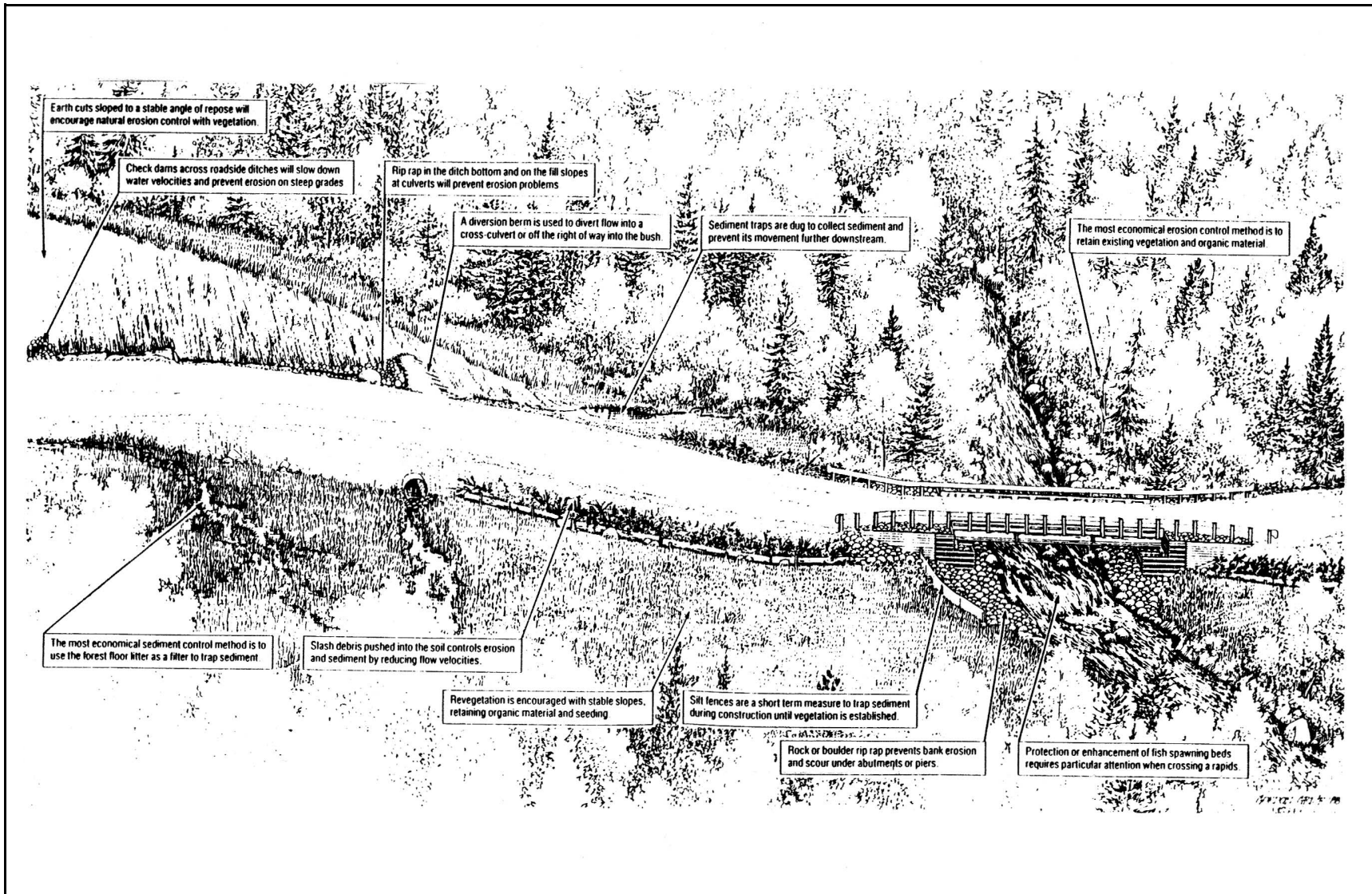


Figure 3-13. Mitigation techniques used for controlling erosion and sediment to protect water quality and fish habitat (Ontario MNR, 1988).

Road Surface Shape and Composition

The shape of a road is an important component of runoff control. Terminology related to road construction and road shape is illustrated in Figure 3-14. Road drainage and runoff control are obtained by shaping the

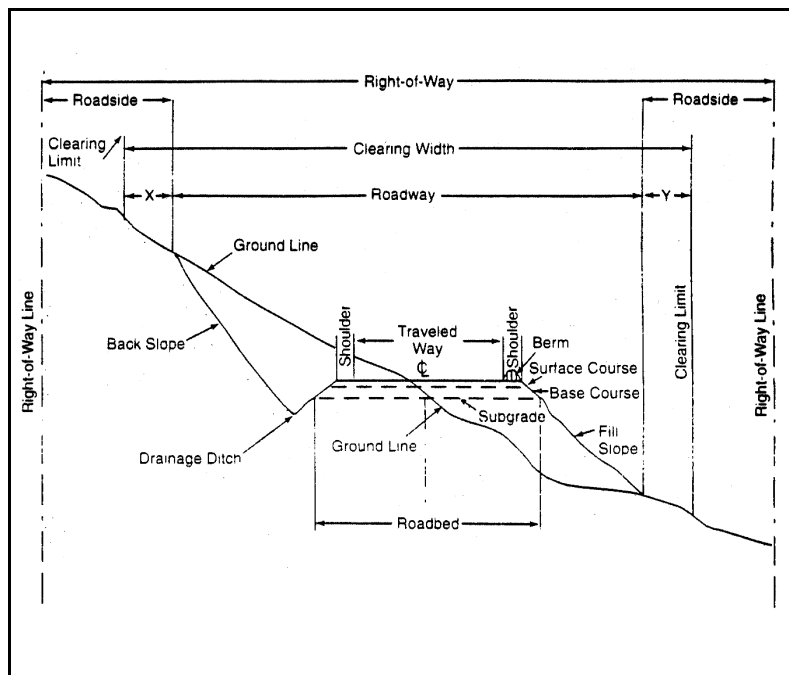


Figure 3-14. Illustration of road structure terms (Moll et al., 1987).

road surface to be insloping, outsloping, or crowned (Figure 3-15). Road surfaces need to have and maintain one of these shapes at all points to ensure good drainage (Moll et al., 1997). Insloping roads can be particularly effective where soils are highly erodible and directing runoff directly to the fill slope would be detrimental. Outsloped roads tend to dissipate runoff more than insloped roads, which concentrate runoff at cross drain locations, and are useful where erosion of the backfill or ditch soil might be a problem. Crowned roads are particularly suited to two-lane roads and to steep single-lane roads that have frequent cross drains or ditches and ditch relief culverts (Moll et al., 1997).

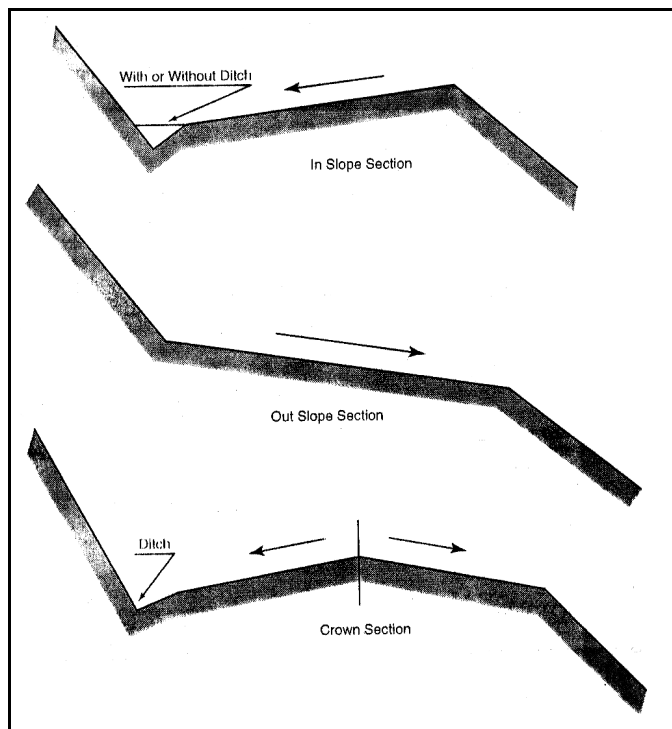


Figure 3-15. Types of road surface shape (Moll et al., 1997).

Sediment Runoff Distance and Quantity Vary with Source

Seventy percent of sediment deposition from roads constructed on three headwater watersheds in the mountains of central Idaho, where the slope ranged from 15 to 40 percent, occurred during the first year after construction, and one-fourth of this occurred during road construction.

Sediment generally traveled less than 100 m from its source. Average sediment travel distances from fills, rock drains, berm drains, and landings were between 4 m and 20 m, while that from cross drains was 50 m. The maximum travel distance from some cross drains was more than 250 m.

The larger source area for runoff from cross drains, including the road prism and upslope watershed areas, accounts for more sediment deposited from them and for the sediment from them traveling farther than from other sources.

(Source: Ketcheson and Megahan, 1996)

Crowns, inslopes, and outlopes will quickly lose effectiveness if not maintained frequently, due to micro-ruts created by traffic when the road surface is damp or wet.

The composition of a road surface is another factor that can be controlled to effectively control erosion from the road surface and slopes. It is important to choose a road surface that is suitable to the topography, soils, and intended use. Road surfaces can be formed from native material, aggregates, asphalt, or other suitable materials, and any of these surface compositions can be shaped in one of the ways discussed above. Surface protection of the roadbed and cut-and-fill slopes with a suitable material can:

- Minimize soil losses during storms
- Reduce frost heave erosion production
- Restrain downslope movement of soil slumps
- Minimize erosion from softened roadbeds

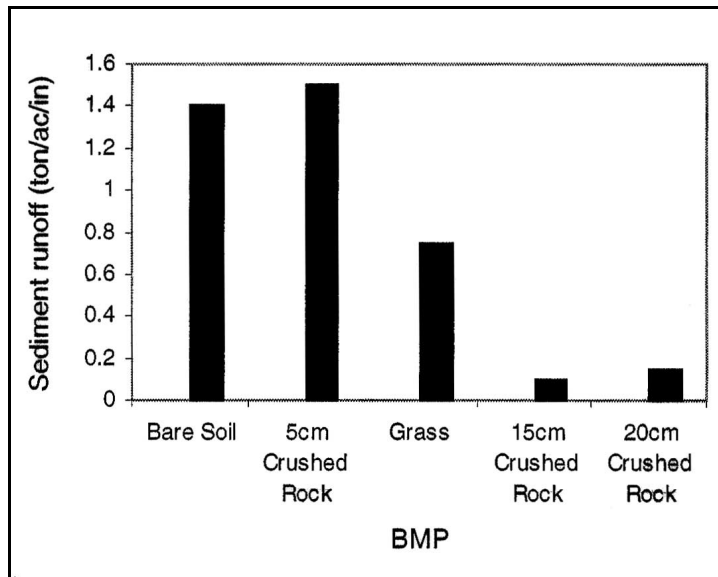


Figure 3-16. Comparison of sedimentation rates (as tons of sediment in runoff per acre per inch of rainfall) from different forest road surfaces (Swift, 1984).

Numerous studies have been conducted and have demonstrated the potential of a suitable road surface composition to control erosion and sedimentation from forest roads. Swift (1985) found that applying 20 centimeters (cm) of crushed rock to forest roads in the southern Appalachian mountains yielded sediment runoff of 0.06 ton/acre/inch of rainfall, a significant reduction from the 1.475 ton/acre/inch of rainfall yielded by a road surface covered by only 5 cm of crushed rock (Figure 3-16). In another study in the Appalachian mountains, Kochenderfer and Helvey (1984) demonstrated that using 1-inch crusher-run gravel or 3-inch clean gravel reduced erosion from road surfaces to less than one-half of that from 3-inch crusher-run gravel, and to only 12 percent of the erosion rate measured from an ungraveled road surface (Table 3-14). In a more recent study (Johnson and Bronsdon, 1995), a surface of bituminous oil or 15 to 20 cm of gravel

reduced erosion rates by as much as 96 percent below that measured from unsurfaced roads (Figure 3-17). In the same study, logging slash left on roads was also found to provide a protective layer and reduced erosion by 75 to 87 percent compared to

Table 3-14. Effectiveness of Road Surface Treatments in Controlling Soil Losses in West Virginia (adapted from Kechenderfer and Helvey, 1984).

| Surface Treatment | Average Annual Soil Losses (tons/acre) ^a |
|---------------------------|--|
| Ungraveled | 44.4 |
| 3-inch crusher-run gravel | 11.4 |
| 1-inch crusher-run gravel | 5.5 |
| 3-inch clean gravel | 5.4 |

^a Six measurements taken over a 2-year period.

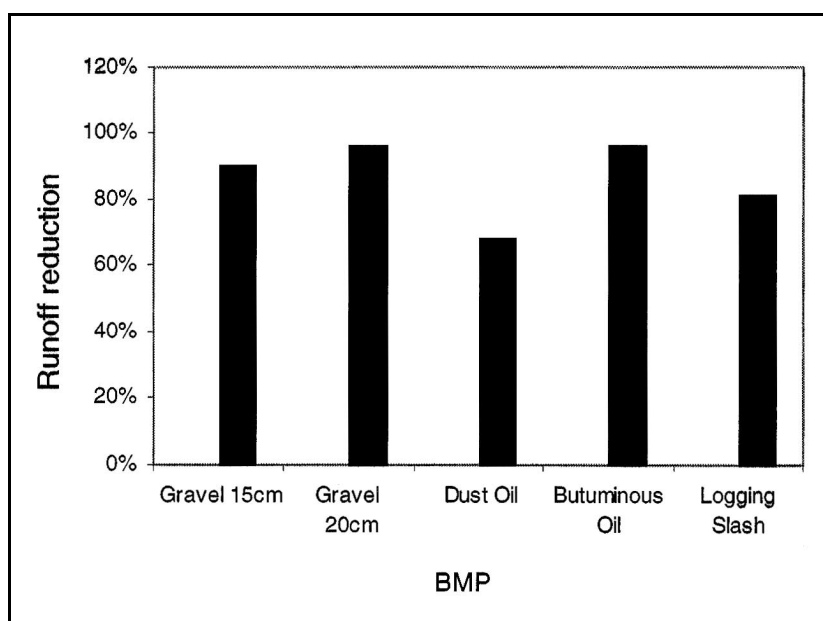


Figure 3-17. Percent of reduction in sediment runoff from a forest road surface with different treatments. Percent reduction in erosion is the amount below that observed on an untreated road (Johnson and Bronsdon, 1995).

unsurfaced roads. Properly shaping a road surface (i.e., insloped, outsloped, or crowned) might not suffice to control drainage adequately, and drainage structures in addition to the relief culverts on insloped and crowned roads might be necessary for drainage control (Moll et al., 1997). Structures such as broad-based dips, turnouts, and cross drains can be used under such conditions, and these BMPs are further discussed below. The proper choice of drainage structure, in combination with the chosen surface shape, and effective installation of the drainage structures is crucial to minimizing erosion from roads and sedimentation in waterbodies.

Improper or insufficient installation of road drainage structures is the cause of many road failures, whereas proper installation of the correct

structure can reduce erosion potential, extend the useful life of a road, and decrease the need for road maintenance.

Slope Stabilization

Road cuts and fills can be a large source of sediment once a logging road is constructed. Stabilizing back slopes and fill slopes as they are constructed is an important process in minimizing erosion from these areas. Combined with graveling or otherwise surfacing the road, establishing grass or using another form of slope stabilization can significantly reduce soil loss from road construction. If constructing on an unstable slope is necessary, as it sometimes is, consider consulting with an engineering geologist or geotechnical engineer for recommended construction methods and to develop plans for the specific road segment. Unstable slopes that threaten water quality should always be considered unsuitable for road building (Weaver and Hagans, 1984).

Planting grass on cut-and-fill slopes of new roads can effectively reduce erosion, and placing forest floor litter or brush barriers on downslopes in combination with establishing grass is also an effective means to reduce downslope sediment transport (Tables 3-15 and 3-16). Grass-covered fill is generally more effective than mulched fill in reducing soil erosion from newly constructed roads because of the roots that hold the soil in place, which are lacking with any other covering placed on the soil. Because grass needs some time to establish itself, a combination of straw mulch with netting to hold it in place can be used to cover a seeded area and effectively reduce erosion during the period while grass is growing. The mulch and netting provide immediate erosion control and promote growth of the grass. Figure 3-18 shows the results of a study conducted by Grace and others (1998) to demonstrate the erosion control capacities of different cut-and-fill slope stabilization BMPs on forest roads. The results of several studies on different types of slope stabilization BMPs are summarized in Table 3-17.

Table 3-15. Reduction in the Number of Sediment Deposits more than 20 Feet Long by Grass and Forest Debris (Swift, 1986).

| Type of Soil Protection | Degree of Soil Protection | Number of Deposits per 1,000 Feet of Road |
|---|---------------------------|---|
| Grassed fill, litter and brush burned | Low | 13.9 |
| Bare fill, forest litter | | 9.9 |
| Mulched fill, forest litter | | 8.1 |
| Grassed fill, forest litter, no brush barrier | ↑ | 6.9 |
| Grassed fill, forest litter, brush barrier | High | 4.5 |

Table 3-16. Comparison of Downslope Movement of Sediment from Roads for Various Roadway and Slope Conditions (Swift, 1986).

| Comparisons | Sites (no.) | Mean Slope (%) | Distance (feet) | | |
|---|-------------|----------------|-----------------|-----|-----|
| | | | Mean | Max | Min |
| All sites | 88 | 46 | 71 | 314 | 2 |
| Barrier ^a | | | | | |
| Brush barriers | 26 | 46 | 47 | 156 | 3 |
| No brush barrier | 62 | 47 | 81 | 314 | 2 |
| Drainage ^b | | | | | |
| Culvert | 21 | 40 | 80 | 314 | 30 |
| Outsloped without culvert | 56 | 47 | 63 | 287 | 2 |
| Unfinished roadbed with berm | 11 | 57 | 95 | 310 | 25 |
| Grass fill and forest litter ^c | 46 | 40 | 45 | 148 | 2 |
| With brush barrier | 16 | 39 | 34 | 78 | 3 |
| With culvert | 4 | 20 | 37 | 43 | 30 |
| Without culvert | 12 | 45 | 32 | 78 | 3 |
| Without brush barrier | 30 | 41 | 51 | 148 | 2 |
| With culvert | 7 | 37 | 58 | 87 | 30 |
| Without culvert | 23 | 42 | 49 | 148 | 2 |

Road Construction and Fish Habitat

The potential for road construction to increase sediment delivery to streams has important implications for certain species of fish. Salmonids and other fish that nest on stream bottoms are very susceptible to sediment pollution due to the settling of sediment that can smother nests and deplete the oxygen available to the eggs. The eggs, buried 1 to 3 feet deep in the gravel redd, rely on a steady flow of clean, cold water to bring oxygen and remove waste products. In coastal streams, eggs hatch in a month or so,

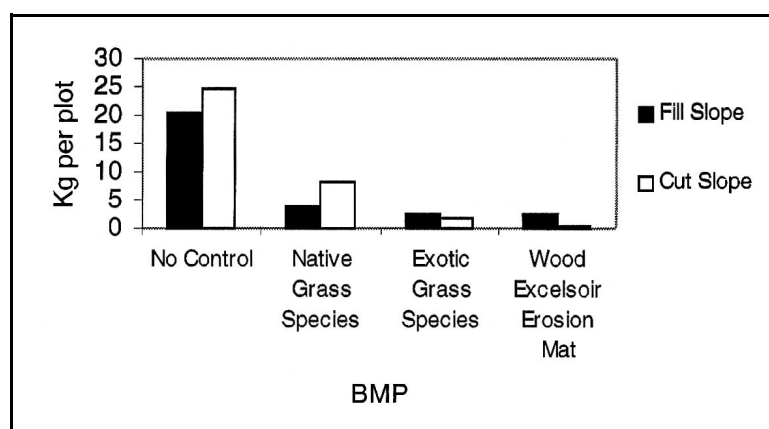


Figure 3-18. Sediment yield from plots using various forms of ground covering. Sediment yield is per plot area over a 6-month period; plots measured 1.5 m x 3.1 m (Grace et al., 1998).

depending on water temperatures and species of fish. Eggs hatch into alevin and remain in the gravel another 30 days or so, living on the nutrients in their yolk sacs. As they develop into fry, the yolk gets used up, and fry emerge through spaces in the gravel to begin life in the stream. During the 60-day period when the eggs and alevin are in the gravel, any shifts of the stream bottom can kill them.

Recent studies in streams on the Olympic Peninsula in Washington found that if more than 13 percent fine sediment (< 0.85 mm) intruded into the redd, no steelhead or coho salmon eggs survived

Table 3-17. Effectiveness of Surface Erosion Control on Forest Roads (adapted from Megahan, 1980, 1987).

| Stabilization Measure | Portion of Road Treated | Percent Decrease in Erosion ^a | Reference |
|---|-------------------------|--|-------------------------------|
| Hydromulch, straw mulch, and dry seeding ^b | Fill slope | 24 to 58 | King, 1984 |
| Tree planting | Fill slope | 50 | Megahan, 1974b |
| Wood chip mulch | Fill slope | 61 | Ohlander, 1964 |
| Straw mulch | Fill slope | 72 | Bethlahmy and Kidd, 1966 |
| Excelsior mulch | Fill slope | 92 | Burroughs and King, 1985 |
| Paper netting | Fill slope | 93 | Ohlander, 1964 |
| Asphalt-straw mulch | Fill slope | 97 | Ohlander, 1964 |
| Straw mulch, netting, and planted trees | Fill slope | 98 | Megahan, 1974b |
| Straw mulch and netting | Fill slope | 99 | Bethlahmy and Kidd, 1966 |
| Straw mulch | Cut slope | 32 to 47 | King, 1984 |
| Terracing | Cut slope | 86 | Unpublished data ^c |
| Straw mulch | Cut slope | 97 | Dyrness, 1970 |
| Wood chip mulch | Road fills | 61 | Bethlahmy and Kidd, 1966 |
| Straw mulch | Road fills | 72 | Ohlander, 1964 |
| Grass and legume seeding | Road cuts | 71 | Dyrness, 1970 |
| Gravel surface | Surface | 70 | Burroughs and King, 1985 |

(McHenry et al., 1994). Chinook salmon are the most susceptible to increased fine sediment, followed by coho salmon, steelhead, and cutthroat trout, respectively (Lotspeich and Everest, 1983). The different tolerances to fine sediment is due to the different head diameters of the fry of the species.

The redd is a depression in the gravel streambed where the eggs are laid, and the depression creates a Venturi effect, drawing water down into the gravel. If the water in the stream above is full of fine sediment, the sediment is drawn down into the redd and smother the eggs.

In a healthy stream, young salmon and trout hide in the interstitial spaces between cobbles and boulders to avoid predation. In streams that become extremely cold in winter, young steelhead may actually burrow into the streambed and spend the winter in flowing water down within the gravel. The area of the stream where flowing water extends down into the gravel is also extremely important for aquatic invertebrates, which supply most of the food for young salmon, steelhead, and cutthroat trout. If fine sediment is clogging interstitial spaces between streambed gravel, juvenile salmonids lose their source of cover and food.

During the year coho salmon spend in freshwater, they prefer pools. High sediment concentrations in the water can cause pools to fill with sediment and reduce or destroy essential coho rearing habitat. Case studies in southwest Oregon showed that streams damaged by logging can also have significant problems with mortality of salmon eggs and alevin (Nawa and Frissell, 1993). When streams are affected by high sediment deposition, these formerly productive low-gradient reaches become wide and shallow and recovery of fish habitat can take decades (Frissell, 1992).

Stream Crossings and Fish Passage

A fishway is any structure or modification to a natural or artificial structure for the purpose of fish passage. Five common conditions at stream crossing culverts create migration barriers (WADOE, 1999):

- Excess drop at culvert outlet
- High velocity within culvert barrel
- Inadequate depth within culvert barrel
- Turbulence within the culvert
- Debris accumulation at culvert inlet

Figure 3-8 illustrates four of these conditions. Barriers to fish passage can be complete, partial, or temporal. Complete barriers block the use of the upper

Stream crossing considerations (Weaver and Hagans, 1984):

- Whether fish use the channel at the crossing site
 - Whether the crossing will be temporary or permanent
 - The type of vehicles that will use the crossing
 - The slope, configuration, and stability of the natural hillslopes on either side of the channel
 - The slope of the channel bed
 - The orientation of the stream to the proposed road
 - The expected 50- and 100-year flood discharge
 - The amount and type of sediment and woody debris that is in transport within the channel
 - The installation and subsequent maintenance costs for the crossing
 - The expected frequency of use
 - Permits and other legal requirements
-

watershed, often the most productive spawning habitat in the watershed for migratory species of fish. Partial barriers block smaller or weaker fish of a population. Culverts are therefore designed to accommodate smaller or weaker individuals of target species, including juvenile fish. Temporal barriers block migration during some part of the year. They can delay some fish from arriving at upstream locations, which for some fish (anadromous salmonids that survive a limited amount of time in fresh water) can cause limited distribution or mortality (WADOE, 1999).

Barriers at culverts can result from improper initial design or installation, or they can be the result of channel degradation that leaves culvert bottoms elevated above the downstream channel. Changes in hydrology due to an extensive road network can be a primary reason for channel degradation, and older culverts that might have been adequate when installed can become inadequate for fish passage when channel degradation or land use changes cause changes in stream channel hydrology (Baker and Votapka, 1990; WADOE, 1999). When such changes occur in a watershed, inspect culverts and, if necessary, replaced them with ones that meet actual specifications.

Other problems at culverts include their not providing the roughness and variability of the adjacent stream channel bottom, which can create short distances of increased water velocity and turbulence (WADOE, 1999). These problems create barriers to the upstream migration of juvenile fish. Fish will not travel upstream under high water velocity conditions (Barber and Downs, 1996).

Water velocity in culverts is a complex issue, involving the length of the culvert in relation to fish capabilities, depth of water, icing and debris flows, and design flows in relation to fish migration upstream or downstream. The size and species of fish passing through a culvert and the magnitude, duration, frequency, and seasonal relationship of the flow to the timing of fish movement have to be considered in setting guidelines for culvert design to meet fish passage requirements (Ashton and Carlson, 1984; Baker and Votapka, 1990).

The addition of baffles to a culvert to affect water velocity and turbulence is not generally recommended because of the regular cleaning that becomes necessary. In addition, it has been found that turbulence at the edge of a baffled culvert actually creates a blockage to fish passage, and in higher-velocity culverts passage success can be higher in smooth pipe (Bates, 1994; Powers, 1996).

Countersunk culverts are recommended where fish passage is desired. Installation of multiple, parallel culverts in place of a larger single culvert is discouraged except in special cases, such as to permit fish passage where flows vary widely (see Figure 3-9). Countersunk culverts allow for natural downstream transport of sediment and a natural stream bottom within the culvert (White, 1996).

Wetland Road Considerations

Sedimentation is also a concern when considering road construction through wetlands. Because of the fragility of these ecosystems, where an alternative route exists, avoid putting a forest access road through a wetland. If it's necessary to traverse a wetland, implement the BMPs suggested by the state. In addition, if road construction or maintenance involves a discharge of dredged or fill material into wetlands or other waters of the United States, section 404(f) requires the application of specific BMPs

designed to protect the aquatic environment. (More information on wetlands and forestry, including a list of the aforementioned BMPs, is provided in section 3J.)

Benefits of Road Construction Practices

Many states have found roads to consistently be sources of sediment discharge to streams. The Vermont Agency of Natural Resources assessed BMP implementation and effectiveness and found that roads were consistently the most problematic with respect to proper BMP implementation. Drainage ditches, culverts, and stream crossings were most frequently the points of origin of stream sedimentation. The Virginia Department of Forestry also found that water control structures on roads are often inadequately used and applied. The Department found that water bars, rolling dips, and broad-based dips were usually installed improperly. Water bars, for instance, were built using fill only, rather than by cutting into the road bed and then using fill material to shape the bar. These structures were often placed too infrequently and too far apart as the road grade increased, and in some cases they were installed backwards, being angled uphill with the outlet pointing upslope.

The Montana Department of Natural Resources and Conservation, Forestry Division, also monitored BMP implementation and effectiveness and similarly found that the most frequent departures from BMP implementation standards and sources of effects were associated with providing adequate road surface drainage, routing road drainage through adequate filtration zones before the runoff entered a stream, maintaining erosion control structures, and providing energy dissipators at drainage structure outlets. The division also found that high-risk BMPs were more frequently not applied properly, and water quality effects from them were common.

The Virginia Department of Forestry assessed BMP implementation and effectiveness in 1994 and concluded from the study that although improvement was needed in meeting minimum standards of BMP implementation, properly implemented stream crossings (as well as SMAs and preharvest plans) are crucial to protecting water quality. Where not implemented properly, stream crossings are less effective than they could be. Improper sizing, placement, and installation of culverts are the causes of most failures. Culverts often were found to be too short for the intended roadbed width, and consequently they became clogged or buried. Some culverts were placed improperly, and without correction could have been rendered ineffective or swept away by storm water cutting through fill material.

In general, poor BMP effectiveness can be due to many factors, including:

- A lack of time or willingness to plan timber harvests carefully before cutting begins.
- A lack of skill in or knowledge of designing effective BMPs.
- A lack of equipment needed to implement effective BMPs.
- The belief that BMPs are not an integral part of the timber harvesting process and can be engineered and fitted to a logging site after timber harvesting has been completed.
- A lack of timely implementation and maintenance of BMPs.

Road Construction and Stream Crossing BMP Costs

Costs of silvicultural BMPs for water quality protection are difficult to specify because the need for and design of BMPs varies from site to site with changes in topography, soil, and proximity to water, among other factors. However, with respect to road construction BMPs, some generalizations can be made. In a study of the costs of various forestry practices in the southeastern United States, practices associated with road construction were generally found to be the most expensive, regardless of terrain, and the costs for broad-based dips and water bars increased as slope increased (Lickwar, 1989) (Table 3-18). The proximity of roads to watercourses also increases the cost of road construction because of the increased need to prevent sediment runoff from reaching the surface waters.

Unit cost comparisons for road surfacing practices (Swift, 1984a) revealed that grass is the least expensive alternative at \$272 per kilometer of road (1998 dollars) (Table 3-19). Initial material costs alone, however, are misleading because a durable road surface can endure several years of use, whereas a grassed or thinly graveled surface will generally need regular maintenance and resurfacing. Grass and thin gravel coverings are also likely to result in more erosion and sedimentation. Table 3-20 compares the cost of

Table 3-18. Cost Estimates (and Cost as a Percent of Gross Revenues) for Road Construction (Lickwar, 1989).

| Practice Component | Location | | | | | |
|--------------------|--------------------------|---------|-----------------------------|---------|-------------------------|---------|
| | Steep Sites ^a | | Moderate Sites ^b | | Flat Sites ^c | |
| Stream crossings | \$45 | (0.01%) | \$185 | (0.03%) | \$4,303 | (0.33%) |
| Broad-based dips | \$16,550 | (2.88%) | \$10,101 | (1.49%) | \$4,649 | (0.36%) |
| Water bars | \$12,225 | (2.13%) | \$6,371 | (0.94%) | \$2,999 | (0.24%) |
| Added road costs | \$5,725 | (1.00%) | Not Provided | | Not Provided | |

Note: All costs updated to 1998 dollars.

^a Based on a 1,148-acre forest and gross harvest revenues of \$399,685. Slopes average over 9 percent.

^b Based on a 1,104-acre forest and gross harvest revenues of \$473,182. Slopes ranged from 4 percent to 8 percent.

^c Based on a 1,832-acre forest and gross harvest revenues of \$899,491. Slopes ranged from 0 percent to 3 percent.

Table 3-19. Cost of Gravel and Grass Road Surfaces (North Carolina, West Virginia) (Swift, 1984a).

| Surface | Quantity/km | Unit Cost | Total Cost/km |
|-----------------------------------|---------------------|------------|---------------|
| Grass | 28 kg Ky-31 | \$1.32/kg | \$36.90 |
| | 14 kg rye | \$1.03/kg | \$14.50 |
| | 405 kg 10-10-10 | \$0.189/kg | \$76.89 |
| | 900 kg lime | \$0.052/kg | \$46.59 |
| | Labor and equipment | \$97.49/km | \$97.49 |
| Crushed rock (5 cm) ^a | 425 ton | \$7.34/ton | \$3,120 |
| Crushed rock (15 cm) ^a | 1,275 ton | \$7.34/ton | \$9,361 |
| Large stone (20 cm) ^a | 1,690 ton | \$8.22/ton | \$13,893 |

Table 3-20. Costs of Erosion Control Measures in Idaho (Megahan, 1987).

| Measure | Cost (\$/acre) |
|---|----------------|
| Dry seeding | \$178 |
| Plastic netting placed over seeded area | \$8,124 |

using a single BMP (dry seeding alone) versus using multiple BMPs (seeding in conjunction with plastic netting) to control erosion (Megahan, 1987).

Best Management Practices

Road Surface Construction Practices

- ☐ *Follow the design developed during preharvest planning to minimize erosion by properly timing and limiting ground disturbance operations.*

Verify with site visits that information used during preharvest planning to develop road layout and surfacing designs is accurate. Make any changes to road and road surface construction designs that are necessary based on new information obtained during these site visits.

- ☐ *During road construction, operate equipment to minimize unintentional movement of excavated material downslope.*

- ☐ *Properly dispose of organic debris generated during road construction.*

- Stack usable materials such as timber, pulpwood, and firewood in suitable locations and use them to the extent possible. Organic debris can be used as mulch for erosion control, piled and burned, chipped, scattered, place in windrows, or removed to designated sites. Slash can be useful if placed as windrows along the base of the fill slope. A windrow is created by piling logging debris and unmerchantable woody vegetation in rows on the contour of the land. Arranged in this manner, the slash material provides a barrier to overland flow, prevents the concentration of runoff, and reduces erosion.
- Don't use organic debris as fill material for road construction since the organic material eventually decomposes and causes fill failure.
- Perform any work in the stream channel by hand to the extent practicable. Machinery can be used in the SMA as long as the desired SMA objective is not compromised.

- ☐ *Prevent slash from entering streams and promptly remove slash that accidentally enters streams to prevent problems related to slash accumulation.*

To the extent possible, prevent slash from entering streams. If allowed to stay in streams, it can cause flow or fish passage problems, or dissolved oxygen depression as it decomposes. Leave natural debris in stream channels, and remove only that slash that is contributed during road construction or harvesting. Large woody debris is an important source of energy for aquatic organisms, especially in smaller headwater streams, and it creates habitat diversity important to aquatic invertebrates and young fish. It is

important, therefore, to inspect streams before any work is done near them and to attempt to leave them in a condition similar to that prior to the work.

- *Compact the road base at the proper moisture content, surfacing, and grading to give the designed road surface drainage shaping.*

The predominant source of sediment from logging is from the construction and maintenance of access roads.

The predominant source of sediment associated with forest harvesting is the construction and maintenance of access roads, which contribute as much as 90 percent of the total eroded sediments (Appelbloom et al., 1998). The annual production of sediment from roads can be as high as 100 tons per hectare (40.5 tons per acre) of road surface or more (Grayson et al., 1993; Kockenderfer and Helvey, 1984). Management practices, including gravel surfacing, proper road maintenance, and proper drainage control, can reduce sediment loss. Gravel surfacing has to be of a sufficient depth (e.g., 15–20 cm). Improperly maintained roads can produce up to 50 percent more sediment than properly maintained roads. Since roads can produce large quantities of sediment even when they are well maintained, careful consideration of their placement and management is extremely important to minimizing their effects on water quality.

- *When soil moisture is high, promptly suspend earthwork operations and weatherproof the partially completed work.*

Regulating traffic on logging roads during unfavorable weather is an important phase of erosion control. Construction and logging under these conditions destroy drainage structures, plug up culverts, and cause excessive rutting, thereby increasing the amount and the cost of maintenance.

- *Consider geotextiles for use on any section of road requiring aggregate material layers for surfacing.*

Geotextile is a synthetic permeable textile material used with soil, rock, or any other geotechnical engineering-related materials (Wiest, 1998). Also known as geosynthetics, geotextiles are associated with high-standard all-season roads, but can also be used in low-standard logging roads. Geotextiles have three primary functions: drainage (filtration), soil separation (confinement), and soil reinforcement (load distribution). These functions are performed separately or simultaneously, but not all functions are provided by each type of geotextile, so use care when making a purchase. Geotextiles reduce the amount of aggregate needed, thus reducing the cost of the road (Wiest, 1998).

The location of a geotextile along a forest road does not affect installation procedures. When installing geotextiles, proper procedure includes the following steps:

- Clear the subgrade of sharp objects, stumps, and debris.
- Grade the surface to provide proper drainage and cross-slope shaping.
- Unroll the geotextile on the subgrade. The amount of overlap depends on the load-bearing capacity of the subgrade, and varies from 1.5-3 feet. Sewing may be necessary if the geotextile is to provide reinforcement.
- Place and compact the aggregate fill. Depth of the aggregate is determined by subgrade strength and the anticipated wheel loading (usually between 9 and 24 inches). It might be necessary to back-dump the aggregate onto the geotextile and spread with a dozer or grader. The rock is feathered out, since pushing it onto the

site produces an uneven distribution of the aggregate. Spread the aggregate in the same direction as the geotextile overlap to avoid separation.

- Compact the aggregate by conventional methods.

Streambanks and other slopes with light wave action can be stabilized by placing the revetment material directly on top of the geotextile. Installing the geotextile underneath the revetment material prevents the occurrence of scour which normally takes place along streambanks behind BMPs such as rip-rap. To ensure that the geotextile stays in place, toe it in at the top and bottom.

Geotextiles extend the service life of roads, increase their load-carrying capacity, and reduce the incidence of ruts. These benefits are realized due to the textiles separating aggregate structural layers from subgrade soils while allowing the passage of water.

- ☐ *Protect access points to the site that lead from a paved public right-of-way with stone, wood chips, corduroy logs, wooden mats, or other material to prevent soil or mud from being tracked onto the paved road.*

This practice prevents tracking of sediment onto roadways, thereby preventing the subsequent washoff of that sediment during storm events. When necessary, clean truck wheels to remove sediment before entering a public right-of-way.

- ☐ *Use pioneer roads to reduce the amount of area disturbed and ensure the stability of the area involved.*

Pioneer roads are temporary access ways used to facilitate construction equipment access when building permanent roads. Confine pioneer roads to the construction limits of the surveyed permanent roadway, and it is important that pioneer roads be fitted with temporary drainage structures to prevent erosion, sedimentation, and road deterioration.

- ☐ *If the use of borrow or gravel pits is needed during forest road construction, locate rock quarries, gravel pits, and borrow pits outside SMAs and above the 50-year flood level of any waters to minimize the adverse effects caused by the resulting sedimentation. Avoid excavating below the water table.*

Gravel mining directly from streams causes a multitude of effects, including destruction of fish spawning sites, turbidity, and sedimentation. During the construction and use of rock quarries, gravel pits, or borrow pits, either divert runoff water onto the forest floor or pass it through one or more settling basins. Revegetate and reclaim rock quarries, gravel pits, spoil disposal areas, and borrow pits upon abandonment.

Road Surface Drainage Practices

- ☐ *Install surface drainage controls at intervals that remove storm water from the roadbed before the flow gains enough volume and velocity to erode the surface. Avoid discharge onto fill slopes unless the fill slope has been adequately protected. Route discharge from drainage structures onto the forest floor so that water disperses and infiltrates. Methods of road surface drainage include the following:*

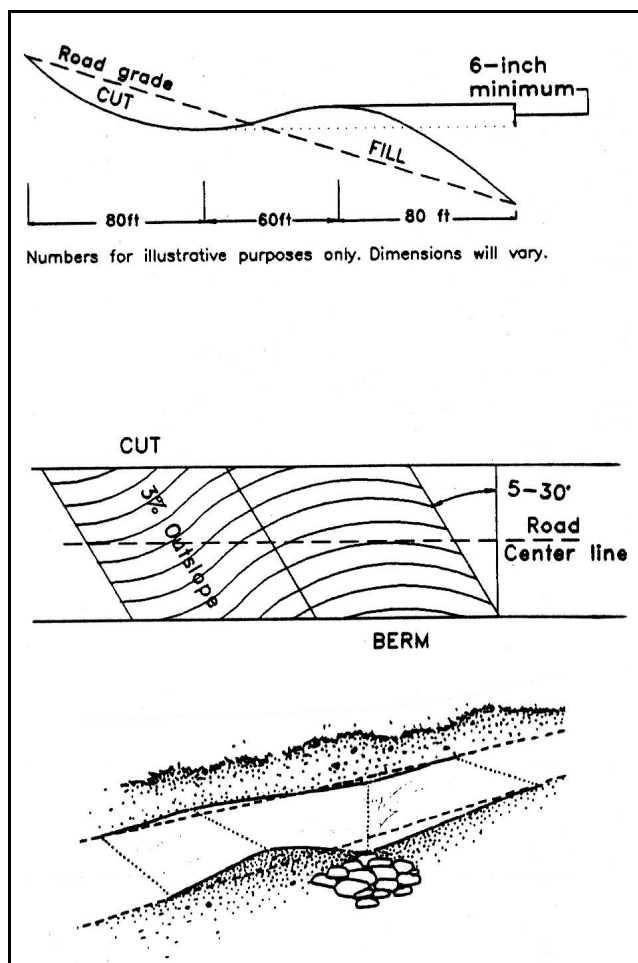


Figure 3-19. Broad-based dip installation. A broad-based dip is a portion of road sloped to carry water from the inside edge to the outside onto natural ground (Minnesota DNR, 1995; Montana State University, 1990).

- *Broad-based dips.* A broad-based dip is a gentle roll in the centerline profile of a road that is designed to be a relatively permanent and self-maintaining water diversion structure that can be traversed by any vehicle (Figure 3-19). Outslope dips 3 percent to divert storm water off the roadbed and onto the forest floor, where transported soil can be trapped by forest litter. Use broad-based dips on roads having a gradient of 10 percent or less because on steeper grades they can be difficult for loaded trucks to traverse (Kochenderfer, 1995). Dips can be difficult to construct on very rocky sections of roads as well.

- *Road outsloping, Insloping, Crowning, and Grading.* Water accumulation on road surfaces can be minimized by grading and insloping or outsloping roadbeds (Figure 3-20). This minimizes erosion and the potential for road failure. Outsloping involves grading a road so that the entire width of the road slopes down the hill it is cut into, and it is appropriate when fill slopes are stable and drainage won't flow directly into stream channels. Outsloping the roadbed keeps water from flowing next to and undermining the cutbank, and it is intended to spill water off the road in small volumes along its length. Give the width of the road a 2 to 3 percent outslope. In addition to outsloping the roadbed, construct a short broad-based dip to turn water off the surface. The effectiveness of outsloping is limited by roadbed rutting during wet conditions. Providing a berm on the outside edge of an outsloped road during construction,

and until loose fill material is protected by vegetation, can eliminate erosion of the fill. A continuous berm (i.e., a low mound of soil or gravel built along the edge of a road) along a roadside can reduce total sediment loss by an average of 99 percent over a standard graded soil road surface (Applebloom et al., 1998). Berms need to have openings provided to allow water to drain off the road surface at appropriate locations where a suitable infiltration or sediment trap site is reached (Swift and Burns, 1999). Construct berms high enough to contain the storm water, and wide enough and with a coarse material to prevent their erosion. Berms are also installed over culvert crossings to prevent runoff from draining directly into streams. A graveled road surface or a grassed strip on the edge of the driving surface can reduce total loss of sediment from roads by up to 60 percent over a standard graded soil road surface. Also, natural berms can form along the edge of older roadbeds or at drainage locations on constructed berms over time and block drainage. Proper maintenance, therefore, is necessary.

Insloped roads carry road surface water to a ditch along the cutbank (Figure 3-21). Ditch gradients of between 2 and 8 percent usually perform best. Slopes greater than

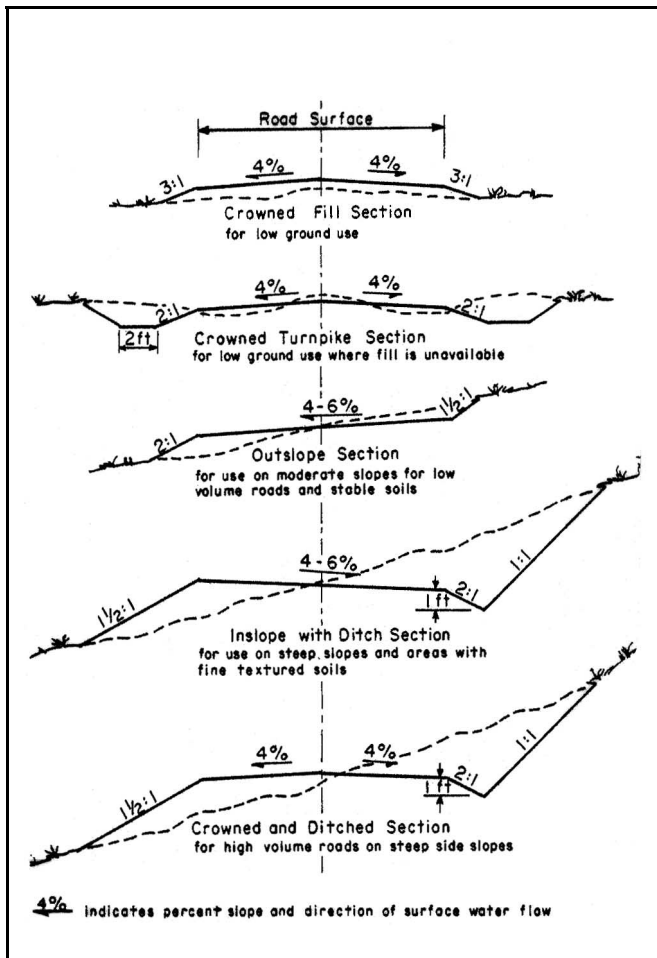


Figure 3-20. Typical road profiles for drainage and stability. Choice of cross section depends on drainage needs, soil stability, slope, and expected traffic volume. Dashed lines indicate natural land contour and solid lines indicate constructed road (Wiest, 1998).

8 percent give runoff waters too much momentum and enough erosive force to carry excessive sediment and debris for long distances, and slopes of less than 2 percent tend to cause water to drain too slowly and do not provide the runoff with enough energy to move accumulated debris with it. The ditch grade also depends on the soil type—nearer to 2 percent on less stable soils and nearer to 8 percent on stable soils.

A crowned road surface is a combination of both an outsloped and insloped surface with the high point (crown) at the center of the road (Moll et al., 1997). The crowned road provides drainage to both sides of the roadway, and a drainage ditch is usually placed next to the road on the insloped side. Properly spaced and sized culverts then direct the runoff to an appropriate grassed buffer, detention basin, or other sediment control structure.

- **Relief culverts.** Relief culverts move water from an inside ditch to the outside edge of a road for dispersion. The culverts should protrude from both ends at least 1 foot beyond the fill and be armored at inlets to prevent undercutting and at outlets to prevent erosion of fill or cut slopes (Figure 3-22). Where the slope on the cutslope above a culvert is steep, as is often the case because of the need to cut into the slope to accommodate the culvert opening, soil erosion above culverts and culvert plugging might be a problem. Installing a riser pipe on the inlet end of a culvert with holes or slits cut at a proper height to allow water to enter (which depends on the amount

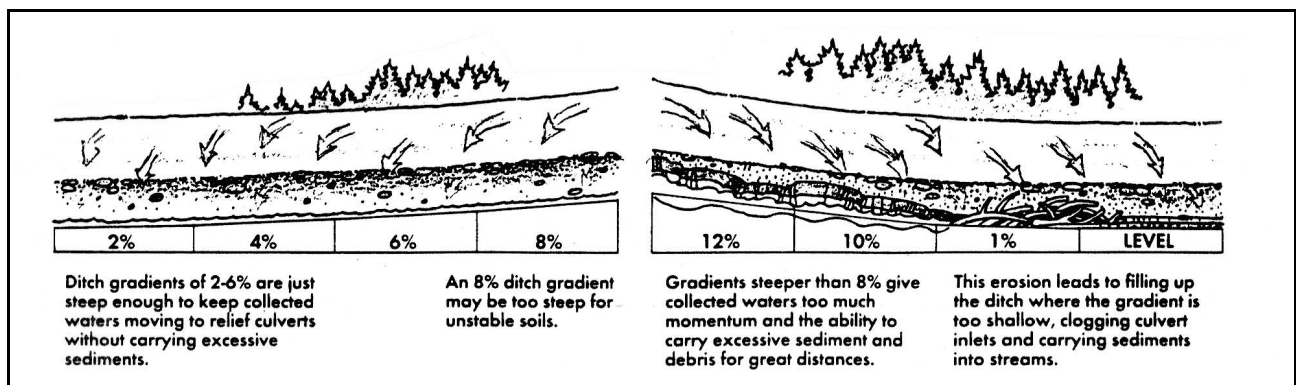


Figure 3-21. Effects of different ditch gradients on insloped roads (Montana State University, 1991).

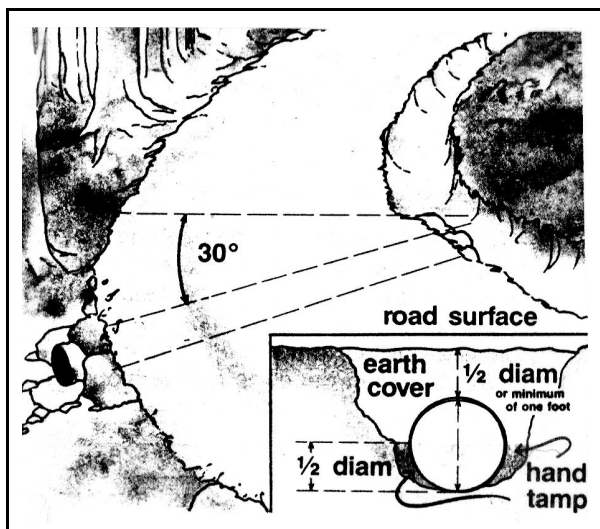


Figure 3-22. Design and installation of relief culvert (Vermont DFPR, 1987).

of soil eroding and flow in the ditch) can prevent plugging while allowing runoff drainage. A ditch dam will reinforce the entrance of water into the culvert through the riser holes (Firth, 1992).

- *Open-top or pole culverts.* Open-top or pole culverts are temporary drainage structures that are most useful for intercepting runoff flowing down road surfaces (Figure 3-23). They can also be used as a substitute for pipe culverts on roads of smaller operations, if properly built and maintained, but don't use them for handling intermittent or live streams. Place open-top culverts at angles across a road to provide gradient to the culvert and to ensure that no two wheels of a vehicle hit it at once. For an open-top culvert to function properly, careful installation and regular maintenance are necessary.

Open-top culverts are recommended for ongoing operations only and are best removed upon completion of forestry activities (Wiest, 1998). These culverts generally slope below the perpendicular to the road at 10 to 45 degrees. Additional maintenance can be necessary as the angle approaches 10 degrees because at this angle debris tends to accumulate; an angle of 30 to 45 degrees is usually recommended (Wiest, 1998).

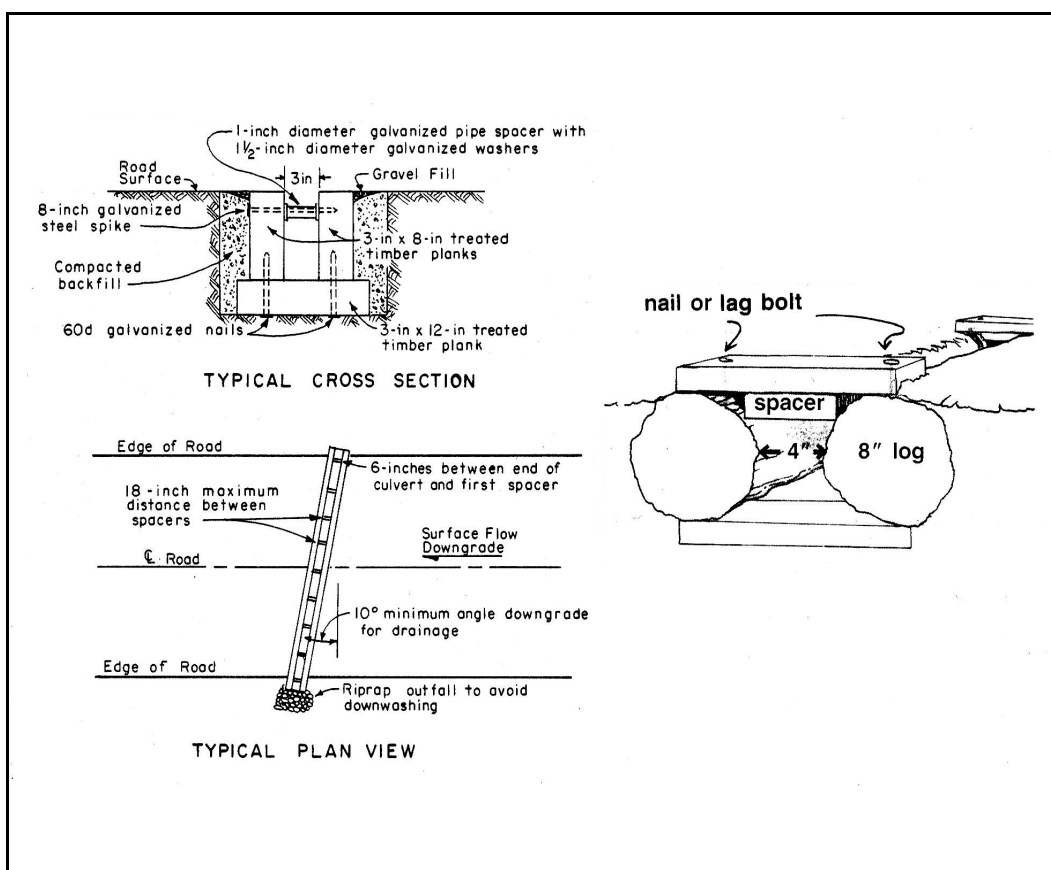


Figure 3-23. Details of installation of open-top (left) and pole (right) culverts (Wiest, 1998; Vermont DFPR, 1987).

Open-top culverts constructed of 8-inch or 10-inch pipe are useful as a supplemental means of runoff control on steep sections of roads where broad-based dips are difficult to install and difficult for trucks to traverse (Kockenderfer, 1995). They are also useful on excessively rocky sections of roads where broad-based dips are difficult to construct. Rectangular openings spaced evenly along the top of a piece of pipe direct runoff into the pipe, and unbroken spacings between the openings provide structural integrity. The culverts can be installed by hand and can be removed and used elsewhere when a road is decommissioned. Their trenches are shallower than those for pole culverts. Discharges from all types of culverts can be controlled using plastic corrugated culvert piping cut in half or, where something that blends in with the surroundings is desired, with riprap (Kockenderfer, 1995). Diversions or in-ditch dams can be placed in ditches to ensure that flow in ditches is directed into culverts and it does not bypass culverts and continue to gain momentum and erosive force.

- *Ditches and turnouts.* Use ditches only where necessary to discharge water to vegetated areas via turnouts (Figure 3-24). Turnouts should be used wherever there is an adequate, safe outlet site where the water can infiltrate. In most cases, the less water a ditch carries and the more frequently water is discharged, the better. Construct wide, gently sloping ditches, especially in areas with highly erodible soils. Slow the velocity of water by installing check dams, rock dams that intercept water flow, along the ditch or lining the ditch with rocks. Check dams also trap sediment

and need to be inspected for sediment build-up. Additionally, stabilize ditches with rock and/or vegetation and protect outfalls with rock, brush barriers, live vegetation, or other means. Roadside ditches need to be large enough to carry runoff from moderate storms. A standard ditch used on secondary logging roads is a triangular section 45 cm deep, 90 cm wide on the roadway side, and 30 cm wide on the cutbank side. The minimum ditch gradient is 0.5 percent, and 2 percent is preferred to ensure good drainage. Runoff is diverted frequently to prevent erosion or overflow.

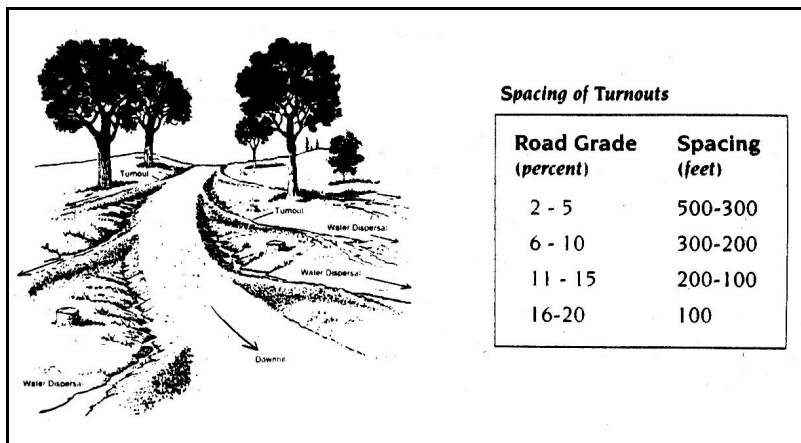


Figure 3-24. Grading and spacing of road turnouts (Georgia Forestry Commission, 1999).

- ☐ *Install turnouts, wing ditches, and dips to disperse runoff and reduce the amount of road surface drainage that flows directly into watercourses.*
- ☐ *Install appropriate sediment control structures to trap suspended sediment transported by runoff and prevent its discharge into the aquatic environment.*

Methods to trap sediment include the following:

- *Sediment traps.* Sediment traps are used downstream of erodible soil sites, such as cuts and fills, to keep sediment from flowing downstream and entering waterbodies (Figure 3-25) (Ontario MNR, 1990). They are located close to the source of sediment

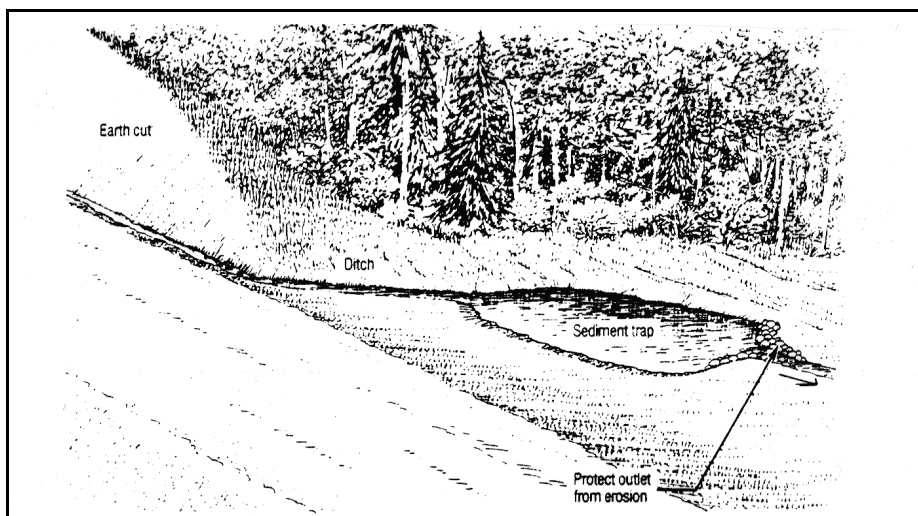


Figure 3-25. Sediment trap constructed to collect runoff from ditch along cutslope (Ontario MNR, 1990).

and preferably in a low area. Use them for drainage areas of less than 5 acres. Size sediment traps so that the expected sediment runoff fills them at about the time that the disturbed area reestablishes vegetation. If sediment accumulates beyond this time, periodic cleaning becomes necessary. Sediment traps are most effective at removing large sediment particles.

- *Brush barriers.* Brush barriers are slash materials piled at the toe slope of a road or at the outlets of culverts, turnouts, dips, and water bars. Install brush barriers at the toes of fills if the fills are located within 150 feet of a defined stream channel. Brush barriers must have good contact with the ground and be constructed approximately on the contour if they are to be effective in minimizing sediment runoff. Figure 3-26

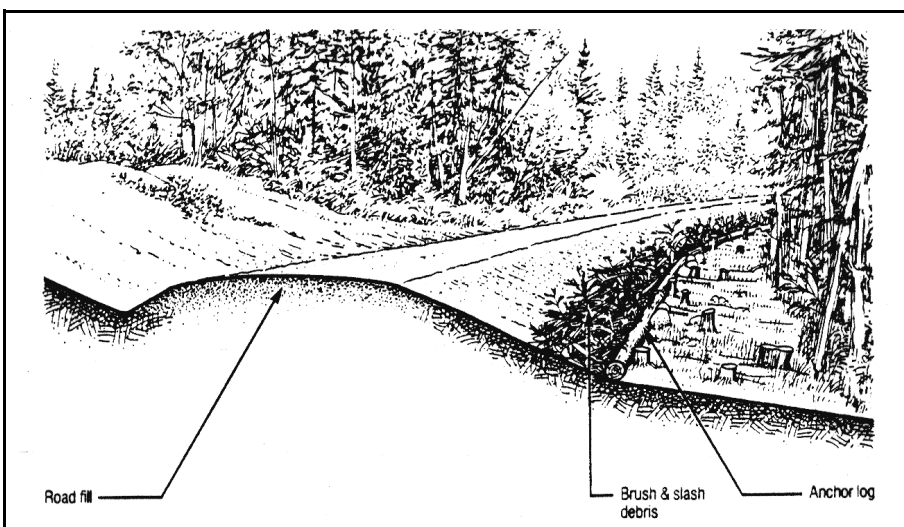


Figure 3-26. Brush barrier placed at toe of fill to intercept runoff and sediment (Ontario MNR, 1990).

shows the use of a brush barrier at the toe of fill. Proper installation is important because if the brush barrier is not firmly anchored and embedded in the slope, brush material can be ineffective for sediment removal and can detach to block ditches or culverts. In addition to use as brush barriers, slash can be spread over exposed mineral soils to reduce the effect of precipitation events and surface flow.

- *Silt fences.* Silt fences are temporary barriers used to intercept sediment-laden runoff from small areas. They act as a strainer: silt and sand are trapped on the surface of the fence while water passes through. They usually consist of woven geotextile filter fabric or straw bales. Install silt fences before earthmoving operations and place them as much along the contour as possible. (Figure 3-27)
- *Filter strips.* Sediment control is achieved by providing a filter or buffer strip between streams and construction activities to use the natural filtering capabilities of

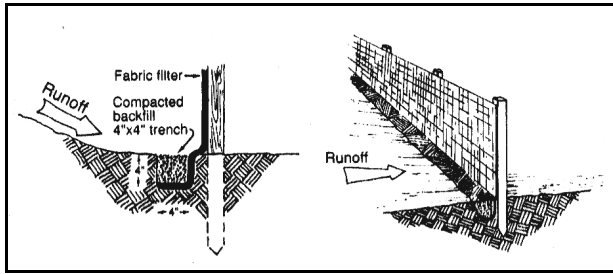


Figure 3-27. Silt fence installation (Wisconsin DNR, 1989).

the forest floor and litter (Figure 3-28). The Streamside Management Area management measure recommends the presence of a filter or buffer strip around all waterbodies. Filter strips are effective at trapping sediment only when the runoff entering them is dispersed. Concentrated flows, such as from culverts, ditches, gullies, etc., entering filter strips will tend to cut a path through the filter strip and render it ineffective.

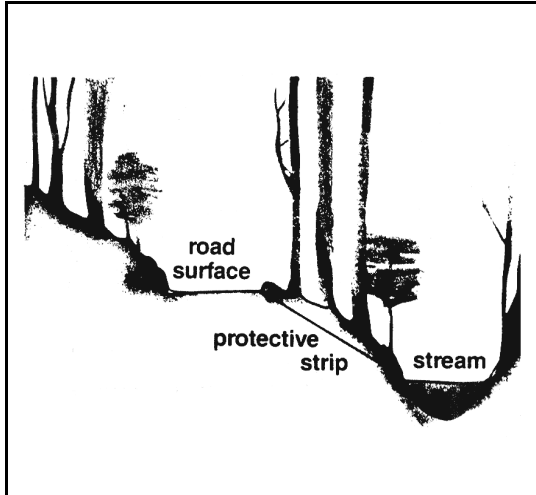


Figure 3-28. Protective filter strip maintained between road and stream to trap sediment and provide shade and streambank stability (Vermont DFPR, 1987).

Foresters with the USDA Forest Service working in the Allegheny National Forest in Pennsylvania inspected numerous roads and streams to determine the minimum length of filter strip between the two that was necessary for preventing sediment from reaching the streams (USDA-FS, 1994, 1995). They found that no matter what the slope, filter strips 100 feet in length are the minimum necessary to prevent sedimentation; in more than a few instances, filter strips as long as 200 feet were necessary. In a test of filtering capacities of roadside erosion control techniques in Tuskegee National Forest in Macon County, Alabama, sediment fences retained 29 percent of runoff sediment, vegetative strips retained 13.5 percent, and sediment below riprap increased by 10 percent. Riprap has no ability to filter sediment from runoff. These findings illustrate the importance of both using guidelines developed for the area where the harvest is to occur and inspecting points where runoff is concentrated (e.g., culvert outlets, turnouts) to see if sedimentation controls are sufficient to protect streams. If sedimentation is found to be occurring despite having installed BMPs

according to specifications, site-specific factors, such as soil type or a sparse herbaceous or litter layer, might have to be accounted for by installing additional sediment control BMPs.

Road Slope Stabilization Practices

- ☐ *Visit locations where roads are to be constructed on steep slopes or cut into hillsides to verify that these are the most favorable locations for the roads.*

Aerial photos and topographic and soil maps can inaccurately represent actual conditions, especially if these media are more than a few years old. Visiting a location where roads are to be cut into slopes or built on steep slopes or where skid trails, landings, and equipment maintenance areas are to be located is valuable for verifying that the information used during planning is accurate. Such visits can also help in determining whether roads can be located to pose less risk of erosion than the risk associated with the locations originally chosen.

- ☐ *Use straw bales, straw mulch, grass seeding, hydromulch, and other erosion control and revegetation techniques to stabilize slopes and minimize erosion (Figure 3-29). Straw bales and straw mulch are temporary measures used to*

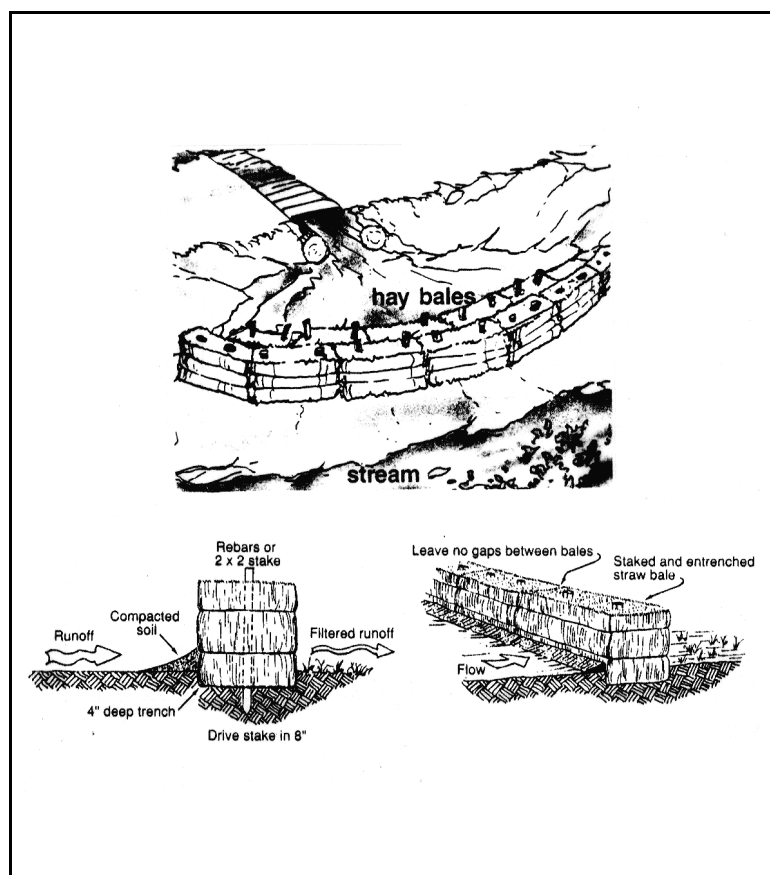


Figure 3-29. Details of haybale installation, used to prevent sediment from skid trails and roads from entering surface waters (Georgia Forestry Commission, 1999; Vermont DFPR, 1987).

protect freshly disturbed soils and are effective when implemented and maintained until adequate vegetation has established to prevent erosion.

- ☐ *Compact the fill to minimize erosion and ensure road stability.*

During construction, fills or embankments are built up by gradual layering. Compact the entire surface of each layer with a tractor or other construction equipment. If the road is to be grassed, do not compact the final layer in order to provide an acceptable seedbed.

- ☐ *Revegetate or stabilize disturbed areas, especially at stream crossings.*

Cutbanks and fill slopes along forest roads are often difficult to revegetate. Properly condition slopes to provide a seedbed, including rolling embankments and scarifying cut slopes. The rough soil surfaces provide niches in which seeds can lodge and germinate. Seed as soon as it is feasible after the soil has been

disturbed, preferably before it rains. Early grassing and spreading of brush or erosion-resisting fabrics on exposed soils at stream crossings are imperative. See the Revegetation of Disturbed Areas management measure for a more detailed discussion.

Stream Crossing Practices

- ☐ *Based on information obtained from site visits, make any alterations to the harvesting plan that are necessary or prudent to protect surface waters from sedimentation or other forms of pollution and to ensure the adequacy of fish passage.*

After preharvest planning has been completed with the aid of aerial photos and/or topographic maps, site visits can be conducted to verify the information used to determine the locations of stream crossings. Photos and maps record the landscape at a moment in time, and changes might have occurred since these media were created. Land use changes in the upper portion of the watershed in which harvesting occurs could have altered streamflow, which in turn might have modified stream corridor characteristics. As a result, alternative stream crossing locations might have to be found. Slopes might be inaccurately represented on topographic maps, and therefore stream crossing approaches or roads near streams might have to be relocated to avoid steep grades, or the width of SMAs might have to be increased. Land use changes in the watershed that

increase streamflow or changes in weather patterns (such as numerous recent years of above-average rainfall) that affect streamflow characteristics might call for larger culverts than those originally intended or a switch from fords to culverts or from culverts to temporary bridges to ensure that fish can pass and that stream crossings can adequately handle streamflow. Refer to *Fish Passage Practices* later in this section for further information on constructing stream crossings that ensure adequate fish passage.

□ *Construct stream crossings to minimize erosion and sedimentation (Figure 3-30).*

Erosion and sedimentation can be minimized by avoiding any operation of machinery in waterbodies. It is especially important to not work in or adjacent to live streams and water channels during periods of high streamflow, intense rainfall, or migratory fish spawning.

Avoid stream crossings whenever practical alternatives are available. When it is necessary to construct stream crossings, install as few of them as possible, select their locations carefully, and select the most appropriate type of stream crossing for the particular site (Blinn et al., 1999). Use existing stream crossings whenever this would affect water quality less than constructing a new one. Make crossings at the narrowest practical portion of a stream and, if possible, cross at a right angle to the stream (Figure 3-30). Crossing at right angles reduces the potential for sediment to be carried down the road and deposited into the stream during a rain event. If the right angle crossing is too long it is likely to be ineffective. Crossing at right angles is not always practical, particularly in gentle topography. Gentle topography does not accelerate runoff into streams as steep angles do. If there is a gentle grade to a stream, the installation of water turnouts and a broad-based dip on each side of the crossing might suffice. This diverts the majority of the water that is runoff down the road. Avoid sags in grades on stream crossings, as they can cause road runoff to enter the stream (Swift and Burns, 1999). Road grade, whether up or down, should be maintained over the length of the crossing and the runoff diverted from the road at the first feasible location after the crossing.

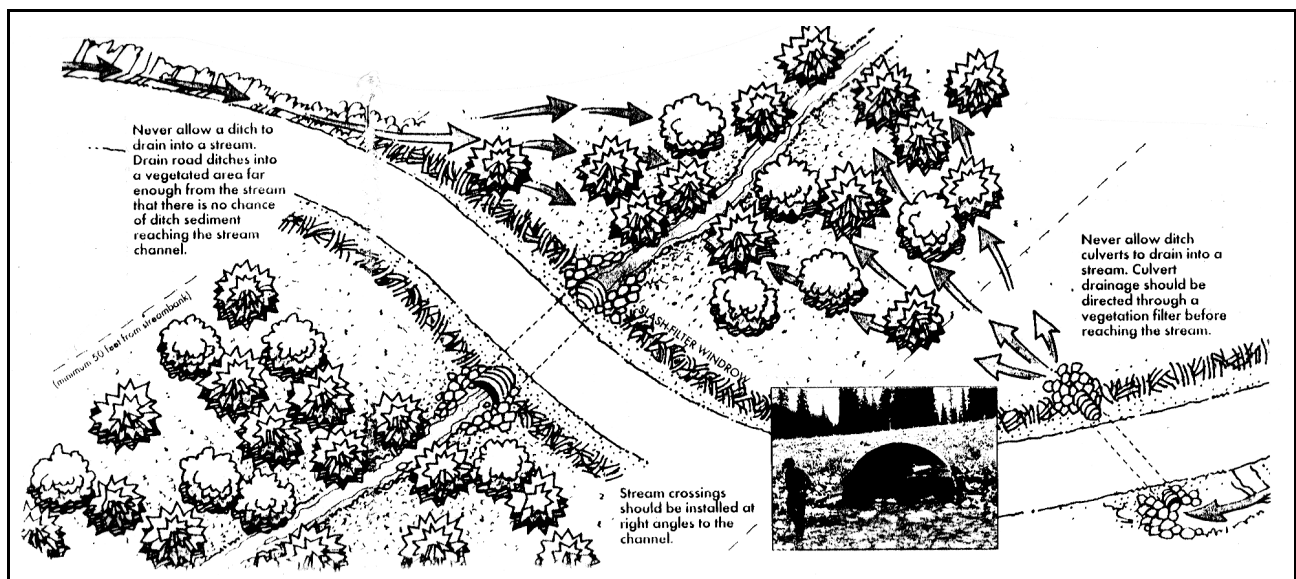


Figure 3-30. Stream crossing installation and road drainage diversion to protect stream water quality (Montana State University, 1991).

Diverting a stream from its natural course is a potential problem when any stream crossing is constructed. When the capacity of a culvert under a stream crossing is too small or a culvert becomes plugged, flow is diverted around the culvert (Furniss et al., 1997). The stream might maintain its natural course (flow across the road parallel to the culvert), or, if the road has an inclining grade across the stream crossing in the direction of streamflow or it slopes downward away from a stream crossing in at least one direction, flow is diverted along the road for a distance until it reaches a low point, flows out of the road, and finds a new course to rejoin the original stream course. If left unchecked, such unintentional diversion can result in very large amounts of erosion and sedimentation and long-term adverse effects to roads and aquatic habitats. Stream diversion can also be caused by accumulations of snow and ice on the road that direct water out of the channel. Diversion potential is greatest on outsloped roads that redirect stream water down a road instead of across it (Best et al., 1995).

Stream diversion is best avoided by properly sizing culverts based on streamflow, constructing crossings such that their grade rises away from the crossing at each approach, inspecting stream crossings regularly after their construction, and maintaining roads and stream crossings properly (Bohn, 1998). Eliminating the potential for stream diversion by properly planning, installing, and maintaining roads and stream crossings is, in the long term, much less expensive and straightforward than attempting to correct improper design and installation after a stream crossing fails (Furniss et al., 1997).

- *Install a stream crossing that is appropriate to the situation and conditions.*

Determining the stream classification and the type of road to be constructed (e.g., temporary, seasonal, or permanent all-weather) is the first step in defining the type of stream crossing to be installed (Weaver, 1994). Design stream crossings to minimize effect on water quality, to handle peak runoff from flood waters, and to allow for adequate fish passage (where fish could be seasonally present). There are three basic subcategories of both permanent and temporary stream crossings: (1) bridges, (2) fords, and (3) culverts.

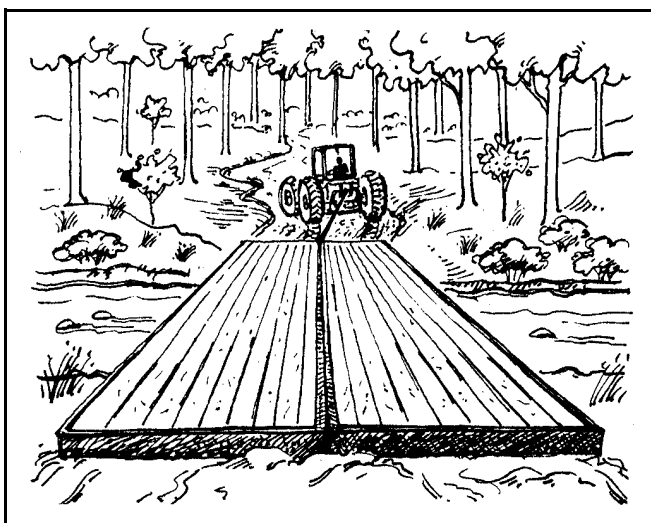


Figure 3-31. Portable bridge for temporary stream crossing (Indiana DNR, 1998).

- *Bridges.* Temporary or portable bridges are being used increasingly because they can be installed and removed with minimal site disturbance or water quality effect and reused (Figure 3-31) (Taylor et al., 1999). Temporary stream crossings can be constructed of polyvinyl chloride and high-density polyethylene pipe bundles, and portable bridges are often constructed of steel (Blinn et al., 1999; Taylor et al., 1999). Approaches on weak soils can be protected with logs, wood mats, wood panels, or expanded metal grating placed over a woven geotextile.
- *Fords.* A ford is a low-water crossings that uses existing or constructed stream bottoms to support vehicles when crossing a stream

(Figure 3-32). A ford is an appropriate stream crossing structure under the following circumstances (Wiest, 1998):

- The streambed has a firm rock or coarse gravel bottom, and the approaches are low and stable enough to support traffic.
- Traffic volume is low.
- Water depth is less than 3 feet.
- Ford will not prevent fish migration.

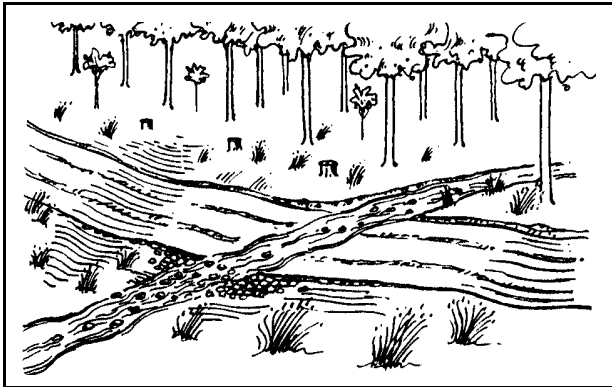


Figure 3-32. A stream ford. Approaches to a ford should be hard and stable (Indiana DNR, 1998).

If log, coarse gravel, or gabion is used to create a driving surface at a stream ford, install the crossing flush with the streambed to minimize erosion and to allow fish passage. Stabilize approaches to the ford using nonerrodible material that extends at least 50 feet from the ford on both sides of the stream crossing.

The following is a common procedure for crossing a small stream where a streambed is not armored with bedrock or an otherwise stable foundation:

- Place several inches of rock down on the streambed. The rock size depends on actual costs, haul distance, and how much is to be installed. Normally, 2 feet or more of rock is installed.
- Place geotextiles over the rock. Geotextile costs approximately \$550 per 1,000 square yards.
- Spread out approximately 1 foot of gravel. The amount and size of gravel varies with the conditions of the stream crossing.

Unless they are very large, stream fords are often the least expensive stream crossing to construct (Taylor et al., 1999). However, they can have greater effects on water quality than other crossings because sediment is introduced during construction and vehicle crossings. They also permit sediment-laden runoff to flow downslope directly into a stream unless adequate runoff diversions are installed.

- *Stream Crossing Culverts.* Stream crossing culverts are placed on roads where a semi-permanent or permanent stream crossing is necessary and to minimize interference with streamflow and stream ecology. Culverts often need outlet and inlet protection to keep water from scouring away supporting material and to keep debris from plugging the culvert. Firmly anchor culverts and compact the earth at least halfway up the side of the pipe to prevent water from leaking around it (Figure 3-33). Energy dissipators, such as riprap and slash, can be useful for this if installed at culvert outlets. If riprap is used for inlet protection, a layer of geotextile should be placed behind the riprap to prevent erosion. Culvert spacing depends on rainfall intensity, drainage area, topography, and amount of forest cover. Most state forestry departments can provide recommendations for culvert pipe diameters.

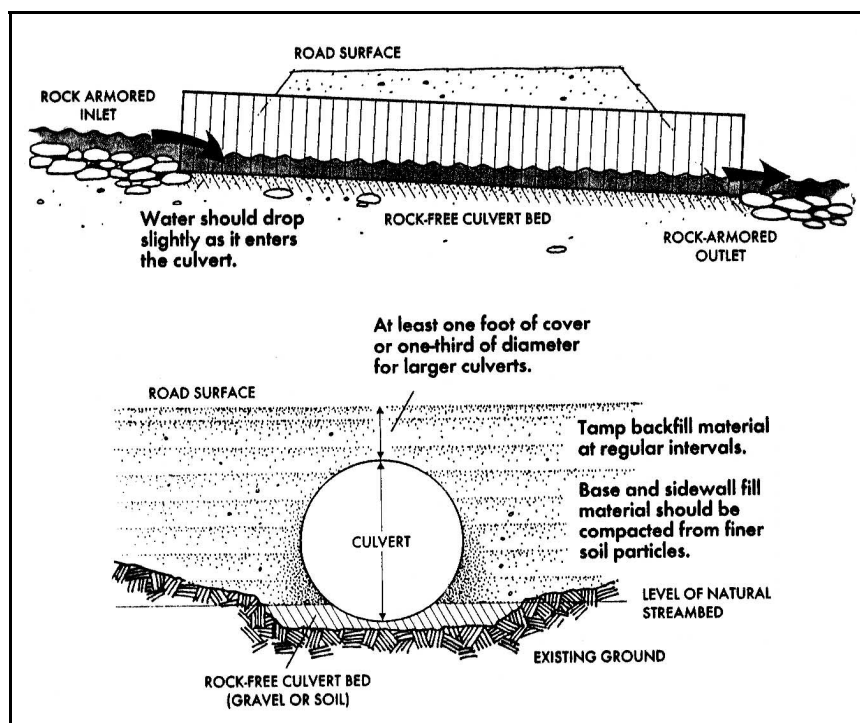


Figure 3-33. Design and installation of pipe culvert at stream crossing (Montana State University, 1991).

According to Murphy and Miller (1997), culverts should be able to handle large flows—at least the 50-year flood. The larger the drainage area leading to a culvert and the steeper the topography, the larger the culvert needs to be to adequately handle the storm flow. If culverts are not properly sized for site-specific factors, culvert blowouts and overtopping can occur. Improper culvert sizing and spacing in Breitenbush, Oregon, led to severe road damage after a storm, and the estimated cost for the additional culverts that would have properly drained the watershed was \$23,500, or 21 percent of the estimated \$110,000 that was necessary to restore the road after the storm (Copstead et al., 1998).

If possible, install arch culverts (Figure 3-7) to avoid disturbance to the stream bottom, or place culverts within the natural streambed (Figure 3-34). Place the inlet on or below the streambed to minimize flooding upstream and to facilitate fish passage. Align large culverts with the natural course and gradient of the stream unless the inlet condition can be improved and the erosion potential reduced with some channel improvement. Use energy dissipators at the downstream end of the culverts to reduce the erosion energy of emerging water.

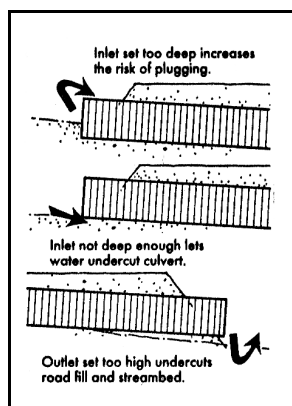


Figure 3-34. Proper installation of culvert in the stream is critical to preventing plugging or undercutting (Montana State University, 1991).

- ☐ *Construct bridges and install culverts during periods when streamflow is low.*
- ☐ *Do not perform excavation for a bridge or a large culvert in flowing water. Divert the water around the work site during construction with a cofferdam or stream diversion.*

Isolating the work site from the flow of water is necessary to minimize the release of soil into the watercourse and to ensure a satisfactory installation in a dry environment. Minimize environmental effects by limiting the duration of construction and by establishing limits on the quantity of surface area disturbed and the equipment to be used. Also, operate when disturbance can most easily be controlled, and use erosion and sediment controls such as silt fences and sediment catch basins. Only use diversions where constructing the stream crossing structure without diverting the stream would result in instream disturbance greater than the disturbance from diverting the stream. Figure 3-35 portrays a procedure for installing a large culvert when

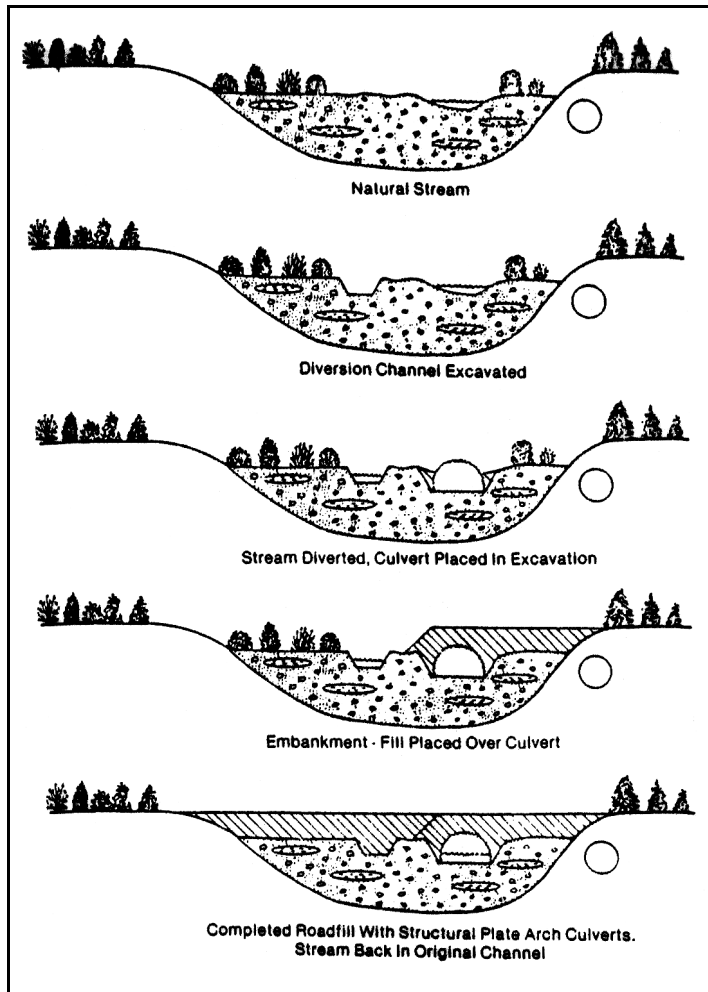


Figure 3-35. Procedure for installing culvert when excavation in channel section of stream could cause sediment movement and increase turbidity (Hynson et al., 1982).

excavation in the channel of the stream would cause sedimentation and increase turbidity.

- ☐ *Protect embankments with mulch, riprap, masonry headwalls, or other retaining structures.*

Some form of reinforcement along streambanks at road stream crossings can reduce sediment loss from these sites (Table 3-21). Soft protection, such as mulch or forest debris, or hard protection, such as gravel or riprap, can be used to protect these vulnerable locations.

- ☐ *Construct ice bridges in streams with low flow rates, thick ice, or dry channels during winter. Ice bridges might not be appropriate on large waterbodies or areas prone to high spring flows.*

Ice bridges can provide acceptable temporary access across streams during winter. Ice bridges are made by pushing and packing snow into streams and applying water to freeze the snow (Figure 3-36). Their use is limited to winter under continuous freezing conditions. A permit might be necessary before an ice bridge crossing can be built, and operators can check this with the appropriate state agency prior to ice bridge construction.

The Minnesota Extension Service (1998) suggests the following when building an ice bridge:

- Choose a period when night temperatures are below 0 °F.
- Make the approaches to the ice bridge nearly level or level.
- Don't add brush or other vegetation to the ice bridge. Doing so weakens the structure and can create a dam when the bridge melts.
- Let the surface freeze; then repeat the construction process until the crossing is of the desired thickness and width.

Table 3-21. Sediment Loss Reduction from Reinforcement at Road Stream Crossings (Rothwell, 1983).

| | Embankment Reinforcement with Mulch | No Reinforcement |
|------------------------------|--|------------------|
| Quantity of Sediment Lost | 566 kg/day/ha | 2,297 kg/day/ha |

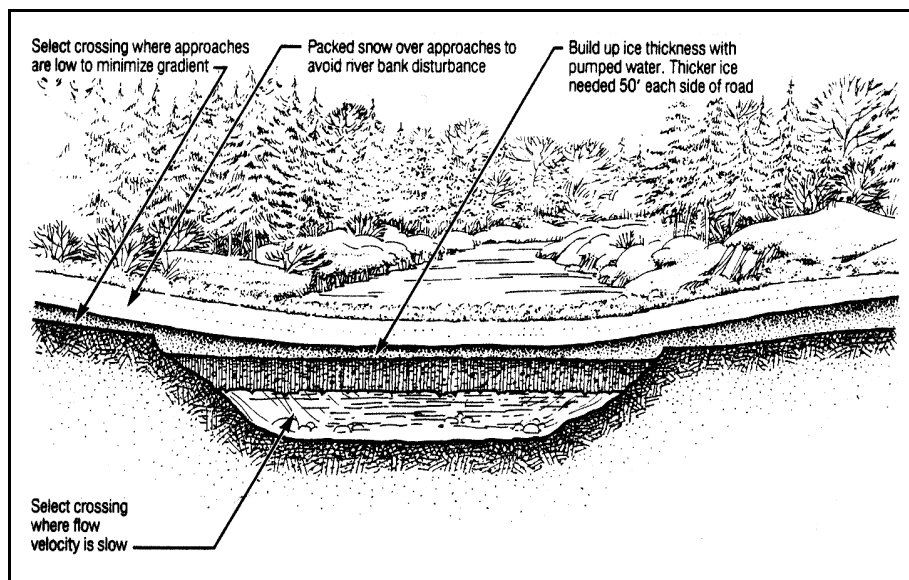


Figure 3-36. Details of ice bridge construction for temporary stream crossing in winter (Ontario MNR, 1990).

- Make the bridge thick enough to permit a level approach.
- Also, make the ice thick enough to support the weight and speed of anticipated traffic.

Inspect the bridge often, because weather and water flow can affect its strength. Properly constructed winter roads have provisions for adequate drainage during winter weather warmups, and for the spring thaw. If a winter thaw occurs, expect to temporarily shut down road travel.

The thaw creates working conditions similar to a wet weather event and causes erosion, severe soil compaction, rutting, and possibly vehicle damage.

Fish Passage Practices

- ☐ *On streams with spawning areas, avoid construction during egg incubation periods.*
- ☐ *Design and construct stream crossings for fish passage according to site-specific information on stream characteristics and the fish populations in the stream where the passage is to be installed.*

The types of structures recommended for use on forest roads as fish passage structures are listed below in order of preference (WADOE, 1999). The choice and design of each is determined by a number of factors, including sensitivity of the site to critical fish habitats, engineering specifications, cost, and availability of materials.

1. Bridges – permanent, semipermanent, and temporary
2. Bottomless culverts or log culverts
3. Embedded metal culverts
4. Nonembedded culverts
5. Baffled culverts

Baffled culverts are the most complicated type of fish passage and are the most difficult to design and construct.

To ensure safe fish passage can be provided without resulting in unacceptable effects on existing fisheries habitat values, consider physical, hydrological, and biological factors to determine whether a structure is acceptable for a site. Review the harvest plan and, based on actual site conditions, make any changes necessary to ensure adequate fish passage. Streamflow, bottom substrate, approach slopes, and soil types on either side of

the stream are some details from the harvest plan to verified at the site prior to constructing stream crossings and installing culverts. The minimum site data for any proposed bridge or major culvert include:

- Cross section showing the high water mark and profile of water crossing.
- Description of waterbody bed materials.
- Presence or absence of and depth to bedrock.
- Water velocity and direction.
- Bankfull width and depth.
- Bottom channel width.
- Channel topography, including gradient for the site and reach.
- Assessment of natural sediment and debris loading and any other condition that might influence the choice, design, and location of a structure.
- Existing improvements and resource values that might influence the structure.

Minimum biological data for successful stream crossing design include:

- Species of fish that you'll want to safely pass
- Size of fish that will pass (life stage)
- Time of year in which fish passage occurs
- High and low design passage flows

The success of any fish passage structure depends very much on channel adjustments that occur after construction of the stream crossing, so it is important to survey far enough upstream and downstream to account for any possible channel conditions that might affect the design and placement of the structure.

3D: Road Management

Management Measure for Road Management

- (1) Avoid using roads where possible for timber hauling or heavy traffic during wet or thaw periods on roads not designed and constructed for these conditions.
- (2) Evaluate the future need for a road and close roads that will not be needed. Leave closed roads and drainage channels in a stable condition to withstand storms.
- (3) Remove drainage crossings and culverts if there is a reasonable risk of plugging or failure from lack of maintenance.
- (4) Following completion of harvesting, close and stabilize temporary spur roads and seasonal roads to control and direct water away from the roadway. Remove all temporary stream crossings.
- (5) Inspect roads to determine the need for structural maintenance. Conduct maintenance practices, when conditions warrant, including cleaning and replacement of deteriorated structures and erosion controls, grading or seeding of road surfaces, and, in extreme cases, slope stabilization or removal of road fills where necessary to maintain structural integrity.
- (6) Conduct maintenance activities, such as dust abatement, so that chemical contaminants or pollutants are not introduced into surface waters to the extent practicable.
- (7) Properly maintain permanent stream crossings and associated fills and approaches to reduce the likelihood (a) that stream overflow will divert onto roads and (b) that fill erosion will occur if the drainage structures become obstructed.

Management Measure Description

The objective of this management measure is to ensure the management of existing roads to maintain their stability and utility; to minimize erosion, polluted runoff from roads and road structures, and sedimentation in waterbodies; and to ensure that roads no longer needed are properly closed and decommissioned so they pose minimal risk to water quality.

Roads that are actively maintained reduce the potential for erosion to occur. Road drainage structures, road fills in stream channels, and road fills on steep slopes are of greatest concern with respect to water quality protection in road management. Roads actively used for timber hauling usually need the most maintenance, and mainline roads typically need more maintenance than spur roads. Regular road use by heavy trucks, especially at stream crossings, creates a chronic source of sediment runoff to streams (Murphy and Miller, 1997). It is important to inspect and repair roads prior to heavy use, especially during wet or thawing ground conditions (Weaver and Hagans, 1984). Use of roads during wet or thaw periods can result in excessive sediment loading to waterbodies when road surfaces become deeply rutted and drainage becomes impaired. The first rule of maintaining a stable road surface is to minimize hauling and grading during wet weather conditions, especially if the road is unsurfaced (Weaver and Hagans, 1984).

Sound planning, design, and construction measures often reduce road maintenance needs after construction. Roads constructed with a minimum width in stable terrain, and with



Figure 3-37. Unmaintained and unused roads can develop severe erosion problems. This shows a person walking in what used to be a roadbed at a level even with the surrounding terrain (Humboldt State University, 1999).

frequent grade reversals or dips, need minimum maintenance. Unfortunately, older roads remain one of the greatest sources of sediment from managed forestlands. After harvesting is complete, roads are often forgotten, and erosion problems might go unnoticed until after severe resource damage has occurred (Figure 3-37). Routine maintenance of road dips and road surfaces and quick response to drainage problems can significantly reduce road deterioration and prevent the creation of ruts that could channelize runoff (Ontario Ministry of Natural Resources, 1988; Oregon Department of Forestry 1981). Roads and drainage structures on all roads, including decommissioned roads for as long as water quality effects might result from them,

should be inspected annually, at a minimum, prior to the beginning of the rainy season (Weaver and Hagans, 1984). Also inspect and perform emergency maintenance during and following peak storms.

In some locations, problems associated with altered surface drainage and diversion of water from natural channels results in serious gully erosion or landslides. In western Oregon, 41 out of the 104 landslides reported on private and state forestlands during the winter of 1989-90 were associated with older (built before 1984) forest roads. These landslides were related to both road drainage and original construction problems. Smaller erosion features, such as gullies and deep ruts, are far more common than landslides and very often are related to poor road drainage.

Sedimentation from roads can be reduced significantly if drainage structures are maintained to function properly. Culverts and ditches that are kept free of debris are less likely to restrict water flow and fish passage. Routinely cleaning these structures can minimize clogging and prevent flooding, gullying, and washout (Kochenderfer, 1970). Fish passage was discussed in the last management measure as an issue of proper sizing and installation of culverts and other stream crossings, and it is equally important to inspect culverts, fords, and bridges on a regular basis to ensure that debris and sediment do not accumulate and prevent fish migration. Undercutting of culvert entrances or exits can create vertical barriers to fish passage, and debris buildup at the entrances of culverts or at trash racks can prevent fish migration. If roads are no longer in use or won't be needed in the foreseeable future, removing drainage crossings and culverts where there is a risk of plugging or failure from lack of maintenance is a precautionary measure. Where a road will be used in the future, it is usually more economical to periodically maintain crossing and drainage structures than not to do so and to have to make extensive repairs after failure.

Road Reconstruction

Road reconstruction provides the opportunity to upgrade and improve substandard and old roads that are no longer used. After an on-site inspection of the entire route and consideration of the economic and environmental costs of the reconstruction, a decision

about reopening a road can be made. Reconstruction might be economically feasible for a particular road but could entail unacceptable environmental costs. Roads where stream crossings have been washed out or short, steep sections of road have been entirely lost to progressive erosion or landsliding are examples of roads where the environmental costs of reconstruction might be too high (Weaver, 1994). In such cases, it might be possible to lessen the environmental damage incurred in reconstruction by rerouting the road around problem areas with a section of new road. Factor overall project costs into the economic and environmental costs of any rerouting to determine its feasibility, and do all road reconstruction in a manner consistent with the Management Measure for Road Construction.

Washed-out stream crossings are the most common obstacle to effective road reconstruction. Initial improper sizing of drainage structures or their not being installed or maintained properly results in erosion at stream crossings. When reconstructing stream crossings, it is important to follow the same design and installation procedures as are used for new crossings.

Road Decommissioning

Proper closure, decommissioning, and obliteration are essential to preventing erosion and sedimentation on roads and skid trails that are no longer needed or that have been abandoned (Swift and Burns, 1999). Road closure involves preventing access by placing gates or other obstructions (such as mounds or earth) at road access points while maintaining the road for future use. Roads that will no longer be used or that have remained unused for many years may be decommissioned and obliterated. Decommissioning typically involves stabilizing fills, removing stream crossings and culverts, recontouring slopes, reestablishing original drainage patterns, and revegetating disturbed areas (Harr and Nichols, 1993; Kochenderfer, 1970; Rothwell, 1978). Revegetating disturbed areas protects the soil from rainfall and binds the soil, thereby reducing erosion and sedimentation and the potential for mass wasting in the future. Because closed roads and trails are rarely inspected, it is important to leave them in as stable a condition as possible to prevent erosion that could become a large problem before any damage is noticed (Rothwell, 1978).

Road decommissioning can significantly reduce water quality effects from unused roads, and road closure and decommissioning can help realize many objectives and purposes (Harr and Nichols, 1993; Moll, 1996):

- Eliminate or discourage access to roads to reduce maintenance expenditures.
- Eliminate the potential for drainage structure failure and stream diversion.
- Reduce soil loss, embankment washout, mass wasting, failures, slides, slumps, sedimentation, turbidity, and damage to fish habitat.
- Provide cover and organic matter to soil, and improve the quality of wildlife and fish habitat.
- Enhance the visual qualities of road corridors and disturbed areas.
- Attempt to restore the natural pre-road hydrology to the site.

Benefits of Road Management

Proper road maintenance has definite economic benefits. In one comparison of road maintenance costs over time, maintenance costs on a road where BMPs were not installed initially were 44 percent higher than costs on a road where BMPs were installed initially (Dissmeyer and Frandsen, 1988) (Table 3-22).

In another economic study, the costs of various revegetation treatments and associated technical services (e.g., planning and reviewing the project in the field) were compared to the benefits over time of the initial planning and BMP installation (Dissmeyer and Foster, 1987) (Table 3-23). Savings resulted from avoiding problem soils, wet areas, and unstable slopes, and the analysis demonstrated that including soil and water resource

Table 3-22. Comparison of Road Repair Costs for a 20-Year Period With and Without BMPs^a (Dissmeyer and Frandsen, 1988).

| Maintenance Costs Without BMPs | | Costs of BMP Installation | |
|---------------------------------------|---------|--|---------|
| Equipment | \$365 | Labor to construct terraces and water diversions | \$ 780 |
| Materials (gravel) | 122 | Materials to revegetate | 120 |
| Work supervision | 40 | Cost of technical assistance | 300 |
| Repair cost per 3 years | 527 | Total cost over 20 years | \$1,200 |
| Total cost over 20 years ^b | \$2,137 | | |

IRR: 11.2%

PNV: \$937

B/C ratio: 1.78 to 1.00 for road BMP installation versus reconstruction/repair.

^aBMPs include construction of terraces and water diversions, and seeding.

^bDiscounted @ 4%.

Table 3-23. Analysis of Costs and Benefits of Watershed Treatments Associated with Roads (SE United States) (Dissmeyer and Foster, 1987).

| | Treatment ^a | | |
|---|------------------------|-----------------|----------------------|
| | Seed Without Mulch | Seed With Mulch | Hydroseed With Mulch |
| <u>Costs</u> | | | |
| Cost per kilometer (\$) | 511 | 816 | 1,006 |
| Cost per kilometer for soil and water technical services (\$) | 89 | 89 | 89 |
| Total cost of watershed treatment (\$) | 600 | 905 | 1,095 |
| <u>Benefits^b</u> | | | |
| Savings in construction costs (\$/km) | 446 | 446 | 446 |
| Savings in annual maintenance costs (\$/km) | 267 | 267 | 267 |
| Benefit/cost (10-year period) | 4.4:1 | 2.9:1 | 2.4:1 |

All costs updated to 1998 dollars

Adapted from West, S., and B.R. Thomas, 1982. Effects of Skid Roads on Diameter, Height, and Volume Growth in Douglas-Fir.

Soil Sci. Soc. Am. J., 45:629-632.

^aTreatments included fertilization and liming where needed.

^bCost savings were associated with soil and water resource management in the location and construction of forest roads by avoiding problem soils, wet areas, and unstable slopes. Maintenance cost savings were derived from revegetating cut and fill slopes, which reduced erosion, prolonging the time taken to fill ditch lines with sediment and reducing the frequency of ditch line reconstruction.

management (i.e., revegetating and technical services) in road planning and construction is more economical over the long term.

As part of the Fisher Creek Watershed Improvement Project, Rygh (1990) examined the costs of ripping and scarification using different techniques and specifically compared the relative advantages of using track hoes for ripping and scarification versus using large tractor-mounted rippers. Track hoes were found to be preferable to tractor-mounted rippers for a variety of reasons, including the following:

- A reduction in furrows and resulting concentrated runoff caused by tractors
- Improved control over the extent of scarification
- Increased versatility and maneuverability of track hoes
- Cost savings

The study concluded that the cost of ripping with track hoes ranged from \$406 to \$506 per mile compared to \$686 per mile for ripping with D7 or D8 tractors (1998 dollars) (Table 3-24).

Table 3-24. Comparative Costs of Reclamation of Roads and Removal of Stream Crossing Structures (ID) (Rygh, 1990).

| Method | Cost (dollar/mile) |
|---|--------------------|
| Ripping/scarification | |
| Ripping with D7 or D8 tractor | \$686 |
| Scarifying with D8-mounted brush blade | \$1,053 |
| Scarification to 6-inch depth and installation of water bars with track hoe | \$2,086 |
| Ripping and slash scattering with track hoe | \$549 - \$823 |
| Ripping, slash scattering, and water bar installation with track hoe | \$1,013 |
| Ripping with track hoe | \$406 - \$506 |

All costs updated to 1998 dollars

Road decommissioning, however, can be expensive. The estimated cost for small roads with gentle terrain and few stream crossings is approximately \$22,500; for larger roads with greater slope and larger and more stream crossings, the cost can equal or exceed \$282,000 (1998 dollars) (Glasgow, 1993).

Best Management Practices

Road Maintenance Practices

- ☐ *Blade and reshape the road to conserve existing surface material; to retain the original, crowned, self-draining cross section; and to prevent or remove berms*

(except those designed for slope protection) and other irregularities that retard normal surface runoff.

Ruts and potholes can weaken road subgrade materials by channeling runoff and allowing standing water to persist. Erosion from forest roads is a process associated with their location, construction, and use, and erosion begins with the development of ruts and the erosion of fine material from the road surface (Johnson and Bronsdon, 1995). Severe rutting on a road can cause drivers to seek routes around the ruts and lead to traffic's moving closer to riparian areas and stream channels, essentially widening a road and magnifying the problem (Phillips, 1997). Natural berms can develop on regularly used roads at undesirable locations and can trap runoff on the road instead of allowing it to drain off at design locations. Natural berms can also develop from improper road grading or gradual entrenchment of the road below the surrounding terrain (Swift and Burns, 1999). If serious road degradation due to rutting or other causes has occurred, the road can be regraded, and periodic regrading of roads is usually necessary to fill in wheel ruts and reshape roads. Regrading a road removes ruts, but it exposes more fine sediment that continues to erode for some months after grading until a protective, coarser layer on the road surface is developed. Serious rutting can indicate the need for a more durable surface.

- *Maintain road surfaces by mowing, patching, or resurfacing as necessary.*

Annual roadbed mowing and periodic trimming of encroaching vegetation is usually sufficient for grassed roadbeds carrying fewer than 20 to 30 vehicle trips per month.

- *Clear road inlet and outlet ditches, catch basins, culverts, and road-crossing structures of obstructions as necessary.*

Avoid undercutting back slopes when cleaning silt and debris from roadside ditches. Minimize machine cleaning of ditches during wet weather. Do not disturb vegetation

when removing debris or slide blockage from ditches. The outlet edges of broad-based dips need to be cleaned of trapped sediment to eliminate mud holes and prevent the bypass of storm water. The frequency of cleaning depends on traffic load.

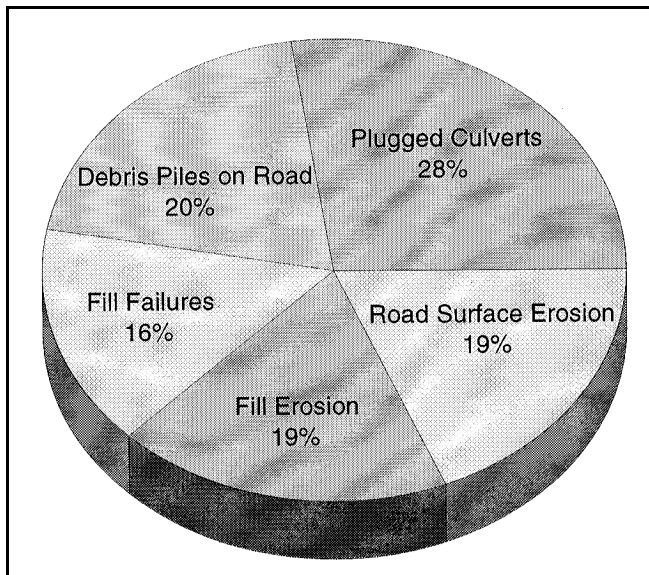


Figure 3-38. Road-related storm damage by type in the Detroit Ranger District (Copstead and Johansen, 1998).

Clear stream-crossing structures and their inlets of debris, slides, rocks, and other materials before and after any heavy runoff period. Surveys by Copstead and Johansen (1998) of the roads in the Detroit Ranger District after storm damage showed that plugged culverts accounted for a greater percentage of damage to the roads than any other cause (Figure 3-38). Culverts were plugged by stream bedload and woody debris. Many times a small branch caught in the culvert inlet caused stream bedload to accumulate, eventually burying the inlet. Undersized culverts accounted for 81 percent of the plugged culverts.

Although regular cleaning of road ditches and culvert inlets and outlets is important, there are circumstances under which leaving accumulated debris in ditches is sometimes called for to help prevent erosion. Some debris might be left in ditches simply to interrupt the free flow of runoff down the ditch, thus reducing the velocity of the runoff and erosion as well.

During road construction, the cut slope is often undercut to provide the design flow capacity in roadside ditches or to provide room for culvert inlets, and undercut slopes are usually unstable. Especially above culvert inlets, soil erosion on the cut slope can lead to high maintenance costs. If, based on experience gained after the road is constructed, the flow in the ditch is less than it was designed for, leaving the accumulated debris in the ditch can help stabilize the cut slope above it. If debris has to be cleared out of a portion of ditch that repeatedly fills with sediment to provide sufficient volume for runoff flow, an option is to build a permanent or temporary passage under the accumulated debris and leave the debris to help stabilize the slope above the ditch. A temporary underpass can be constructed of two logs placed parallel with a gap between them and a third log on top. A permanent underpass can be constructed much like a culvert (Firth, 1992).

- ☐ *Remove any debris that enters surface waters from a winter road or skid trail located over surface waters before a thaw.*
- ☐ *Return the spring following a harvest and build erosion barriers on any skid trails that are steep enough to erode.*
- ☐ *Abate dust problems during dry summer periods.*

Excessive road dust during the summer is a condition that can threaten water quality. Dust can deliver large quantities of fine sediment to nearby stream channels. This fine material can be especially damaging to fish and fish habitat. Seasonal summer roads need almost the same amount of maintenance as permanent roads.

Dust control methods such as applying dust oil and watering during dry summer conditions are almost always necessary during an intensive dry season to prevent excessive loss of surface materials.

Wet and Winter Road Practices

- ☐ *Before winter, inspect and prepare all permanent, seasonal, and temporary roads for the winter months.*

Winterizing consists of maintenance and erosion control work needed to drain the road surface (Weaver, 1994). Clean trash barriers, culvert inlet basins, and pipe inlets of floatable debris and sediment accumulations. Clean ditches that are partially or entirely plugged with soil and debris, and trim and remove heavy concentrations of vegetation that impede flow. Gate and close seasonal and temporary roads to nonessential traffic.

Surface runoff problems caused by winter use of a bermed, unsurfaced road can cause rutting. The ruts collect runoff and cause additional erosion of the road. Lack of waterbars or rolling dips, together with the graded berm along the outside edge of the road, keep surface runoff on the roadbed. Annual grading can produce an outside berm of soil and rock that can be graded back onto the road surface.

Winter is a popular time to harvest wetlands or areas that are not accessible during wet periods, and road structures that will have to be maintained during the winter can be marked prior to snowfall. Snow accumulation could otherwise hide the BMPs.

- *On woodland roads “daylight” or remove trees to a width that permits full sunlight to reach the ground.*

The objective of road “daylighting” is to have sunlight dry the road so that it is less susceptible to erosion and damage from vehicle traffic. Daylighting also promotes the establishment of protective vegetative cover on road fillslopes and cutslopes and vegetation for wildlife. Vegetation clearing to promote daylighting needs to be managed so that slope integrity is not compromised. Daylighting should also be coordinated with wildlife specialists so that openings that might be detrimental to certain wildlife species, such as neotropical migratory birds, are not created.

Stream Crossing and Drainage Structure Practices

- *When temporary stream crossings are no longer needed, and as soon as possible upon completion of operations, remove culverts and log crossings to maintain adequate streamflow. Restore channels to pre-project size and shape by removing all fill materials used in the temporary crossing.*

Failure or plugging of abandoned temporary crossing structures can result in greatly increased sedimentation and turbidity in the stream, as well as channel blowout.

- *Replace open-top culverts with cross drains (water bars, dips, or ditches) to control and divert runoff from road surfaces.*

Open-top culverts are for temporary drainage of ongoing operations. It is important to replace them with more permanent drainage structures to ensure adequate drainage and reduce erosion potential prior to establishment of vegetation on the roadbed. It is recommended that open-top culverts be used for ongoing operations only and that they be removed upon completion of activities (Wiest, 1998).

- *During and after logging activities, ensure that all culverts and ditches are open and functional.*

Culvert plugging is common in woodland streams (Flanagan and Furniss, 1997). The risk of culvert plugging is greatest where small culverts have been installed on wide streams. Channel width controls the size of debris that can be transported in a stream, and culverts with a diameter that is less than the width of the stream are prone to block and accumulate woody debris. Another configuration that leads to debris trapping is increasing channel width toward a culvert inlet. Woody debris, transported in a lengthwise position down a stream, can rotate to a position perpendicular to the channel where the channel widens and block the culvert inlet. Hand, shovel, and chainsaw work can remedy almost all culvert maintenance needs (Weaver and Hagans, 1984). Heavy machinery and equipment is usually unnecessary to keep culverts clean.

Where culvert and ditch plugging is a problem, assess the cause of the problem and develop a strategy to correct it (see *Roads Analysis* in the *Management Measure for Preharvest Planning*, subsection 3A). Corrective measures might include installation of

a new culvert, trimming dead wood from overhanging vegetation, or performing regularly scheduled maintenance.

Road Closure and Decommissioning Practices

- *Wherever possible, completely close roads to travel and restrict access by unauthorized persons by using gates or other barriers (Figure 3-39).*

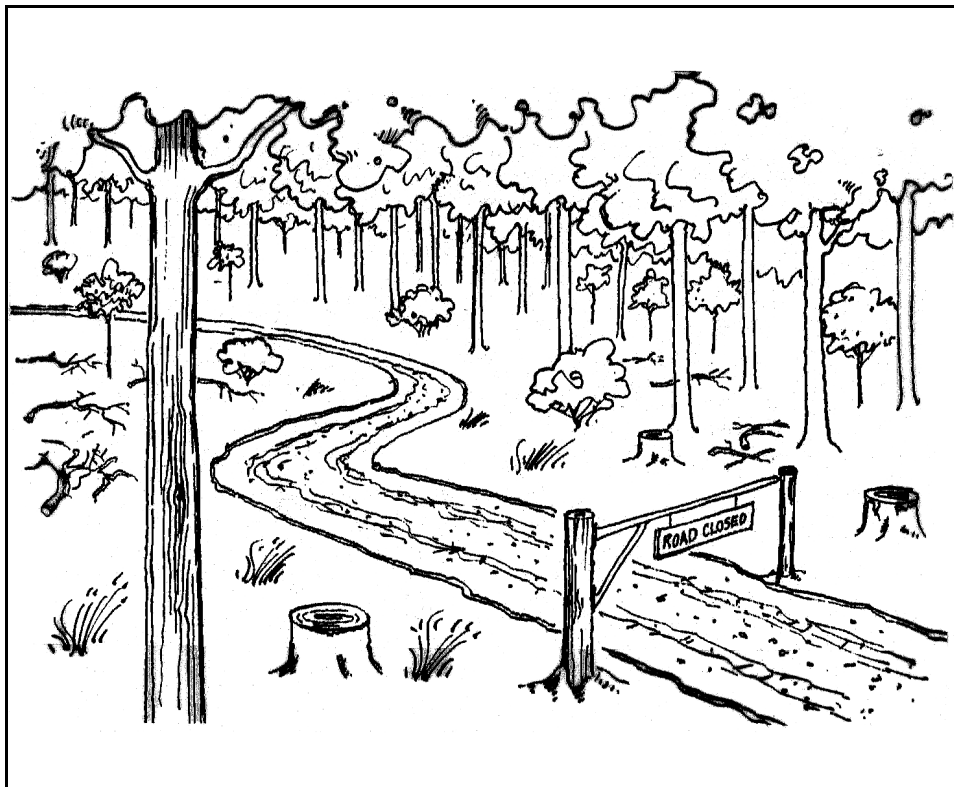


Figure 3-39. Install visible traffic barriers where appropriate to prevent off-road vehicle and other undesired disturbance to recently stabilized roads (Indiana DNR, 1998).

Access can be restricted using rocks, logs, slash piles, or other on-site materials; planted trees; fences, gates; guardrails; concrete barriers; or complete obliteration of a road access point by recontouring and removal of all drainage structures, bridges, and other road features. Regulate traffic where restricting access with such barriers is not feasible.

- *Convert closed forest access roads to use as recreation trails.*

Recreation can involve off-road vehicle use, horseback riding, mountain biking, and hiking. All of these activities create the potential for road or trail damage, and routine maintenance is necessary to ensure that sediment runoff from the closed road does not threaten water quality. The level of maintenance depends on the level, type, and frequency of recreational use.

Trails need the same kinds of runoff control measures as roads, and regular trail maintenance is as important as regular road maintenance (Figure 3-40).

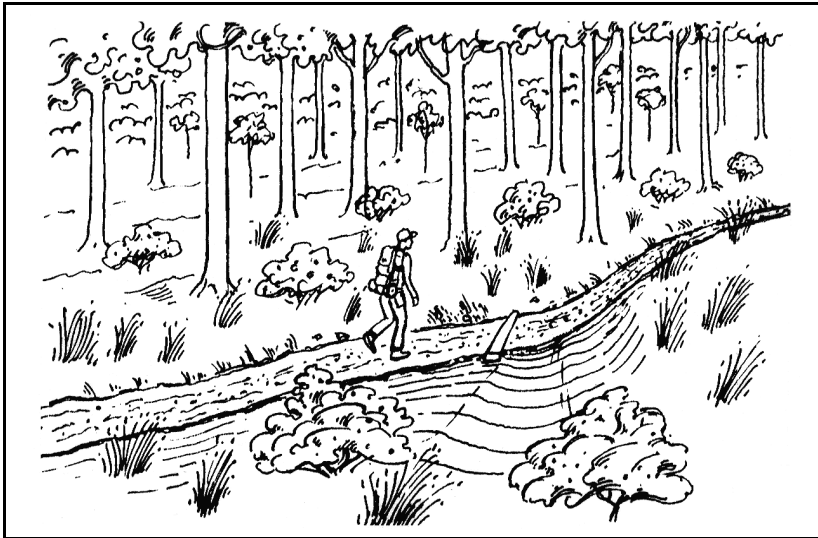


Figure 3-40. Construct trails using the same drainage structures as closed forest roads (Indiana DNR, 1998).

- *Install or regrade water bars on roads that will be closed to vehicle traffic and that lack an adequate system of broad-based dips (Figure 3-41).*

Water bars help to minimize the volume of water flowing over exposed areas and remove water to areas where it will not cause erosion. Water bar spacing depends on soil type and slope. Table 3-25 presents the Oregon Department of Forestry's suggested guidelines for water bar spacing. In other states with different climates, topographies, and soil types, recommended spacing might differ

from these guidelines; contact the state forestry department for assistance. Divert water flow off the water bar onto rocks, slash, vegetation, duff, or other less erodible material and avoid diverting it directly to streams or bare areas. Outslope closed road surfaces to disperse runoff and prevent closed roads from routing water to streams.

- *Periodically inspect closed roads to ensure that vegetational stabilization measures are operating as planned and that drainage structures are operational. Conduct reseeding and drainage structure maintenance as needed.*

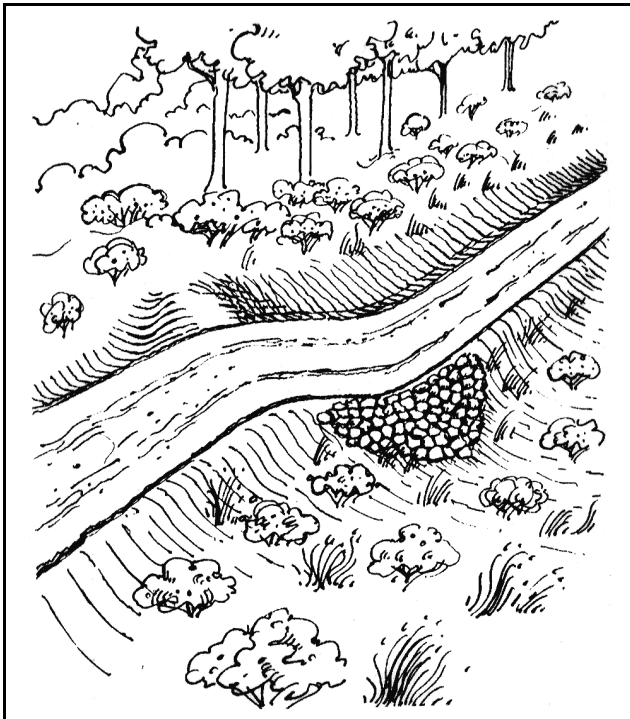


Figure 3-41. Broad-based dips reduce the potential for erosion (Indiana DNR, 1998).

- *Decommission roads that are no longer needed (see Road Decommissioning in this section).*

When a road is not needed for harvesting, forest management activities, or recreation, it can be decommissioned. Effective decommissioning reduces actual and potential erosion from the road and saves maintenance costs. Typically, a road is decommissioned by removing stream crossing fills and culverts, and preparing the surface for planting with vegetation such as grasses and forbs that provide forage for wildlife. If decommissioning is properly done, an area previously occupied by a forest road blends into the surrounding landscape naturally, erode no more than an undisturbed site, and provide wildlife habitat. These are all goals of road decommissioning.

Returning an area with a forest road to its natural drainage characteristics is an important goal of road obliteration. Road decommissioning objectives

Table 3-25. Example of Recommended Water Bar Spacing by Soil Type and Slope (Oregon Department of Forestry, 1979a).

| Road Grade (percent) | Soil Type | | |
|-------------------------|-------------------|-----------------|------|
| | Granitic or Sandy | Shale or Gravel | Clay |
| 2 | 900 | 1000 | 1000 |
| 4 | 600 | 1000 | 800 |
| 6 | 500 | 1000 | 600 |
| 8 | 400 | 900 | 500 |
| 10 | 300 | 800 | 400 |
| 12 | 200 | 700 | 400 |
| 15 | 150 | 500 | 300 |
| 20 | 150 | 300 | 200 |
| 25+ | 100 | 200 | 150 |

Note: Distances (in feet) are approximate and are varied to take advantage of natural features. Recommendations of spacing will vary with soil type, climate, and topography. Consult your state forester.

related to drainage include reducing peak flows that might have been increased by road building and other forest harvesting-related activities, eliminating any alterations in drainage patterns created by a road system, eliminating the potential for drainage structure failure and stream diversion, and reestablishing drainage connectivity that might have been interrupted by the presence of the road (Moll, 1996). Success in accomplishing these goals is aided by examining the drainage characteristics of the entire watershed within which the road to be obliterated lies.

Stabilizing areas disturbed by road construction and use is another major goal of road obliteration. As a plan is developed to return an area to its natural drainage pattern, areas that might be susceptible to erosion after the obliteration is complete are identified and stabilized. Any disturbed slopes, areas with fill, and areas to which drainage will be directed after the obliteration is terminated are areas to investigate. In some cases, artificial means to stabilize slopes might be necessary until vegetation has become established.

Road decommissioning can lead to improvements in fisheries habitat where sediment runoff from old forest roads enters streams. The practice was used in a watershed in northwest Washington as part of watershed rehabilitation to improve fisheries habitats and water quality and to reduce flood hazards. On unused, 30- to 40-year-old, largely impassable roads and landings, fills were stabilized, stream crossings were removed, slopes were recontoured, and drainage patterns were reestablished at an average cost of \$3,950 per kilometer (with a range of \$1,500 to \$7,500 per kilometer) (1998 dollars). Costs were lowest where little earthmoving was involved, more where a lot of brush had to be cleared away and sidecast material had to be pulled upslope, and highest where fills were removed at stream crossings and landings. Afterward, however, the decommissioned roads and landings sustained much less damage from storms than unused roads that were not decommissioned (Harr and Nichols, 1993).

More than 120 miles of roads have been decommissioned in the Targhee National Forest in Idaho (USDA-FS, 1997). Roads in riparian areas were particularly targeted for

decommissioning. The process of decommissioning the roads involved seeding the roads with grasses that provide forage for wildlife and adding water bars to prevent erosion and trap water for wildlife. In the Lake Tahoe Basin, an existing road surface is ripped to a depth of 12 to 18 inches, the surface is seeded, and pine needle mulch is spread on top to prevent erosion and encourage good establishment of vegetation. The road prism and drainage features are left in place to prevent erosion and soil runoff while the vegetation establishes itself. Roads decommissioned by the U.S. Forest Service in Region 8 are similarly seeded to create linear wildlife open areas that provide forage and edge vegetation. The U.S. Forest Service in Region 4, where the Targhee National Forest is located, found that public acceptance of the road closures was enhanced by adding turn-arounds and parking areas at the closure gates.

- ☐ *Revegetate disturbed surfaces to provide erosion control and stabilize the road surface and banks.*

Refer to the Management Measure for Revegetation of Disturbed Areas for a more detailed discussion of this practice.

3E: Timber Harvesting

Timber Harvesting

The timber harvesting management measure consists of implementing the following:

- (1) Follow layouts for timber harvesting operations determined under the Preharvest Planning Management Measure, subject to adjustments made based on preharvest on-site inspections.
- (2) Install landing drainage structures to avoid sedimentation to the extent practicable. Disperse landing drainage over sideslopes.
- (3) Construct landings away from steep slopes and reduce the likelihood of fill slope failures. Protect landing surfaces used during wet periods. Locate landings outside streamside management areas.
- (4) Protect stream channels and significant ephemeral drainages from logging debris and slash material.
- (5) Use appropriate areas for petroleum storage, draining, and dispensing, and vehicle maintenance. Establish procedures to contain and treat spills that could occur during these activities. Recycle or properly dispose of all waste materials.

For cable yarding:

- (1) Limit yarding corridor gouge or soil plowing by properly locating cable yarding landings.
- (2) Locate corridors for streamside management areas according to the guidelines of the Management Measure for Streamside Management Areas.

For groundskidding:

- (1) To the extent practicable, do not operate groundskidding equipment within streamside management areas except at stream crossings. In streamside management areas, fell and endline trees in a manner that avoids sedimentation.
- (2) Use improved stream crossings for skid trails that cross flowing drainages. Construct skid trails to disperse runoff and with adequate drainage structures.
- (3) On steep slopes, use cable systems rather than groundskidding where groundskidding could cause excessive sedimentation.

Management Measure Description

The goal of this management measure is to minimize the likelihood of water quality effects resulting from timber harvesting. This goal can be accomplished by taking precautions to control erosion and sedimentation during harvesting operations and by storing, handling, and disposing of petroleum products and vehicle maintenance products in an environmentally safe manner.

Reducing effects on soils and water quality from harvesting begins in the preharvest planning stage, when a system of roads, landings, and skid trails is planned. Preharvest planning, as described in the Preharvest Planning Management Measure, is performed to minimize the amount of disturbed area, which makes it easier to rehabilitate the site after the operation is complete; locate roads on stable soils to minimize erosion and at a safe distance from streams; build stream crossings at the locations where they cause the least

amount of in-stream disturbance and hydrological change; and limit disturbance to sensitive areas. Thoroughly review the Preharvest Planning Management Measure before incorporating the practices in this management measure into a harvesting plan. The practices in that management measure can serve as a guide for reducing soil disturbance and water quality effects during harvesting. Having a harvesting plan reviewed by a professional forester before starting any aspect of harvesting or road building is strongly recommended. The forester might be able to offer ideas specific to the planned harvest on how environmental damage and operational costs can be reduced.

Do an additional review of the harvesting plan in conjunction with a site visit to verify that the information used during planning is still valid. Aerial photos and topographic and soil maps can inaccurately represent actual conditions, especially if these media are more than a few years old. Before construction begins, verify that the soils and slopes where landings and skid trails are to be located are suitable to the use and that equipment maintenance or chemical handling areas are appropriately located. As the harvest progresses, make any alterations to the harvesting plan necessary to protect soils and water quality.

Conducting a harvest with attention paid to the potential for soil disturbance from the operation can result in significantly less water quality impairment than conducting a harvest with little or no attention paid to the potential for environmental damage. For instance, skid trails that are parallel to the slope of the land have far more potential to yield sediment-laden runoff than skid roads that run along the contour. Similarly, practices that minimize soil compaction on and prevent or disperse runoff from landings and loading decks can be implemented to reduce the potential for sediment-laden runoff and to minimize sediment delivery to surface waters. Incorporating these and other erosion reduction practices into a harvesting plan, conducting an on-site inspection during the planning stage before harvesting or road construction begins to ensure that the practices chosen are appropriate to the site, and properly implementing and maintaining the practices can significantly decrease water quality effects.

Spill prevention and containment procedures are necessary to prevent petroleum products from entering surface waters. Chemicals and petroleum products spilled in harvest areas can be transported great distances if they enter areas of concentrated runoff, and therefore can adversely affect water quality far from where they are spilled. Designating appropriate areas for the storage and handling of petroleum products and protecting these areas from precipitation can minimize the water quality effects that could result from spills or leakage.

Many studies have evaluated and compared the effects of different timber harvest techniques on soil loss (erosion), soil compaction, and overall ground disturbance associated with various harvesting techniques. The data presented in Tables 3-26 through 3-30 were compiled from many studies conducted throughout the United States and Canada. Some of the data presented in the table should be considered as older data that were based on operations conducted prior to current understanding and concern for water quality protection. The studies examined different harvesting systems (e.g., clearcuts, selective harvesting) using a variety of techniques (e.g., cable yarding, skidding). Local factors such as climate, soil type, and topography affected the results of each study. The major conclusions of these studies regarding the relative effects of different timber harvesting techniques on soil erosion, summarized below, are shared among the studies and enable cross-geographic comparison:

Table 3-26. Soil Disturbance from Roads for Alternative Methods of Timber Harvesting (Megahan, 1980).

| Logging System (State) | Percent of Logged Area Bared | | | Reference |
|---|------------------------------|-------------------------------|-------|----------------------------|
| | Roads | Skid Roads and Landings | Total | |
| Tractor: | | | | |
| Tractor — clearcut (BC) | 30.0 | — | 30.0 | Smith, 1979 |
| Tractor — selection (CA) | 2.7 | 5.7 | 8.4 | Rice, 1961 |
| Tractor — selection (ID) | 2.2 | 6.8 | 9.0 | Haupt and Kidd, 1965 |
| Tractor — group selection (ID) | 1.0 | 6.7 | 7.7 | Haupt and Kidd, 1965 |
| Tractor and helicopter — fire salvage (WA) | 4.5 | 0.4 | 4.9 | Klock, 1975 |
| Tractor and cable — fire salvage (WA) | 16.9 | — | 16.9 | Klock, 1975 |
| Ground Cable: | | | | |
| Jammer — group selection (ID) | 25-30 | — | 25-30 | Megahan and Kidd, 1972 |
| Jammer — clearcut (BC) | 8.0 | — | 8.0 | Smith, 1979 |
| High-lead — clearcut (BC) | 14.0 | — | 14.0 | Smith, 1979 |
| High-lead — clearcut (OR) | 6.2 | 3.6 | 9.8 | Silen and Gratkowski, 1953 |
| High-lead — clearcut (OR) | 3.0 | 1.0 | 4.0 | Brown and Krygier, 1971 |
| High-lead — clearcut (OR) | 6.0 | 1.0 | 7.0 | Brown and Krygier, 1971 |
| High-lead — clearcut (OR) | 6.0 | — | 6.0 | Fredriksen, 1970 |
| Skyline: | | | | |
| Skyline — clearcut (OR) | 2.0 | — | 2.0 | Binkley, 1965 |
| Skyline — clearcut (BC) | 1.0 | — | 1.0 | Smith, 1979 |
| Aerial: | | | | |
| Helicopter — clearcut | 1.2 | — | 1.2 | Binkley ^a |

^aEstimated by Virgil W. Binkley, Pacific Northwest Region, USDA Forest Service, Portland, OR.

Table 3-27. Soil Disturbance from Logging by Alternative Harvesting Methods (Megahan, 1980).

| Method of Harvest | Location | Disturbance (%) | Reference |
|--------------------------------|-----------|-----------------|-------------------------------|
| Tractor: | | | |
| Tractor — clearcut | E. WA | 29.4 | Wooldridge, 1960 |
| Tractor — clearcut | W. WA | 26.1 | Steinbrenner and Gessel, 1955 |
| Tractor — fire salvage | E. WA | 36.2 | Klock ^a , 1975 |
| Tractor on snow — fire salvage | E. WA | 9.9 | Klock ^a , 1975 |
| Tractor — clearcut | BC | 7.0 | Smith, 1979 |
| Tractor — selection | E. WA, OR | 15.5 | Garrison and Rummel, 1951 |
| Ground Cable: | | | |
| Cable - selection | E. WA, OR | 20.9 | Garrison and Rummel, 1951 |
| High-lead — fire salvage | E. WA | 32.0 | Klock ^a , 1975 |
| High-lead — clearcut | W. OR | 14.1 | Dyrness, 1965 |
| High-lead — clearcut | W. OR | 12.1 | Ruth, 1967 |
| High-lead — clearcut | BC | 6.0 | Smith, 1979 |
| Jammer — clearcut | BC | 5.0 | Smith, 1979 |
| Grapple — clearcut | BC | 1.0 | Smith, 1979 |
| Skyline: | | | |
| Skyline — clearcut | W. OR | 12.1 | Dyrness, 1965 |
| Skyline — clearcut | E. WA | 11.1 | Wooldridge, 1960 |
| Skyline — clearcut | BC | 7.0 | Smith, 1979 |
| Skyline — clearcut | W. OR | 6.4 | Ruth, 1967 |
| Skyline — fire salvage | E. WA | 2.8 | Klock ^a , 1975 |
| Balloon — clearcut | W. OR | 6.0 | Dyrness ^b |
| Aerial: | | | |
| Helicopter — fire salvage | E. WA | 0.7 | Klock ^a , 1975 |
| Helicopter — clearcut | ID | 5.0 | Clayton (in press) |

^aDisturbance shown is classified as severe.^bDyrness, C.T., unpublished data on file, Pacific Northwest Forest and Range Experiment Station, Corvallis, OR.

Table 3-28. Relative Effects of Four Yarding Methods on Soil Disturbance and Compaction in Pacific Northwest Clearcuts (OR, WA, ID) (Sidle, 1980).

| Yarding Method | Bare Soil (%) | Compacted Soil (%) | Water Quality Effects |
|----------------|---------------|--------------------|------------------------|
| Tractor | 35 | 26 | Greater Lesser |
| High-lead | 15 | 9 | |
| Skyline | 12 | 3 | |
| Balloon | 6 | 2 | |

Table 3-29. Percent of Land Area Affected by Logging Operations (Southwest MS) (after Miller and Sirois, 1986).

| Operational Area | Cable Skyline | Groundskidding | Water Quality Effects |
|--------------------------------|-------------------|-------------------|-----------------------|
| | (% Land Affected) | (% Land Affected) | |
| Cable corridors or skid trails | 9.2 | 21.4 | Greater |
| Landings | 4.1 | 6.4 | |
| Spur roads | 2.6 | 3.5 | Lesser |
| Water Quality Effects | Lesser | Greater | |

Table 3-30. Skidding/Yarding Method Comparison (after Patric, 1980).

| Harvesting System | Acres Served per Mile of Road | Water Quality Effects |
|-------------------|-------------------------------|-----------------------|
| Wheeled skidder | 20 | Greater |
| Jammer | 31 | |
| High-lead | 40 | |
| Skyline | 80 | Lesser |

- Aerial and skyline cable techniques are far less damaging than other yarding techniques.
- Tractor, jammer, and high-lead cable methods result in significantly more soil disturbance and compaction than skyline and aerial techniques.
- Skyline yarding serves far more area per mile of road than skidding.

Although skidding can be damaging, areas disturbed by skidding operations can be rehabilitated without a net economic loss to the landowner. An analysis of the costs and benefits of rehabilitating skid trails in the southeastern United States by planting different species of trees indicated that the benefit/cost ratios of using shortleaf pine, hardwood pine, and hardwoods were 5.1:1, 2.8:1, and 1.3:1, respectively. Shortleaf pine yielded the highest benefit for costs incurred (Dissmeyer and Foster, 1986).

Benefits of Timber Harvesting Practices

After a 1994 study of BMP implementation and effectiveness, the Virginia Department of Forestry concluded that harvesters often failed to seed bare soil with adequate ground cover. The department determined that ground cover of 70 percent or more is effective, while many sites studied had ground cover on only 0 to 35 percent of bare soil. The Vermont Agency of Natural Resources (1998) also studied the effectiveness of erosion control BMPs and concluded that the construction and proper placement of such BMPs

before harvesting is essential for protecting water quality. The Agency also found that regularly maintaining BMPs increased the longevity of their effectiveness.

In general, poor BMP effectiveness can be due to many factors, including:

- A lack of time or willingness to plan timber harvests carefully before cutting begins.
- A lack of skill in or knowledge of designing effective BMPs.
- A lack of equipment needed to implement effective BMPs.
- The belief that BMPs are not an integral part of the timber harvesting process and can be engineered and fitted to a logging site after timber harvesting has been completed.
- A lack of timely BMP maintenance.

Best Management Practices

Harvesting Practices

- ☐ *Based on information obtained from site visits, make any alterations to the harvesting plan that are necessary or prudent to protect soils from erosion and surface waters from sedimentation or other forms of pollution.*
- ☐ *Fell trees away from watercourses whenever possible, keeping logging debris from the channel, except where debris placement is specifically prescribed for fish or wildlife habitat.*
- ☐ *Immediately remove any tree accidentally felled in a waterway.*
- ☐ *Remove slash from the waterbody and place it above the normal high water line or flood to prevent downstream transport.*

Removing slash allows unrestricted water flow and protection of the stream's nutrient balance. Remove only logging-generated debris. Leave pieces of large woody debris in place during stream cleaning to preserve channel integrity and maintain stream productivity. Indiscriminate removal of large woody debris can adversely affect channel stability. Figure 3-42 presents one way to determine debris stability. State forestry or ecology departments can help with such determinations for particular regions and stream types.

- ☐ *Leave sufficient slash throughout the harvest site and distribute it to provide good ground cover and minimize erosion after the timber harvest.*

Leave slash on disturbed soils to minimize erosion until new vegetative growth can protect the soils from erosion. The quantity of slash to leave depends on the erodibility of the soil, though leaving an amount that provides 40 to 60 percent ground cover for soils that have low to high erodibility, respectively, is recommended. Leaving slash on the ground significantly reduces erosion potential. It also keeps the nutrients contained in the slash material on the site, providing them back to the soil and to new growth as the slash decomposes.

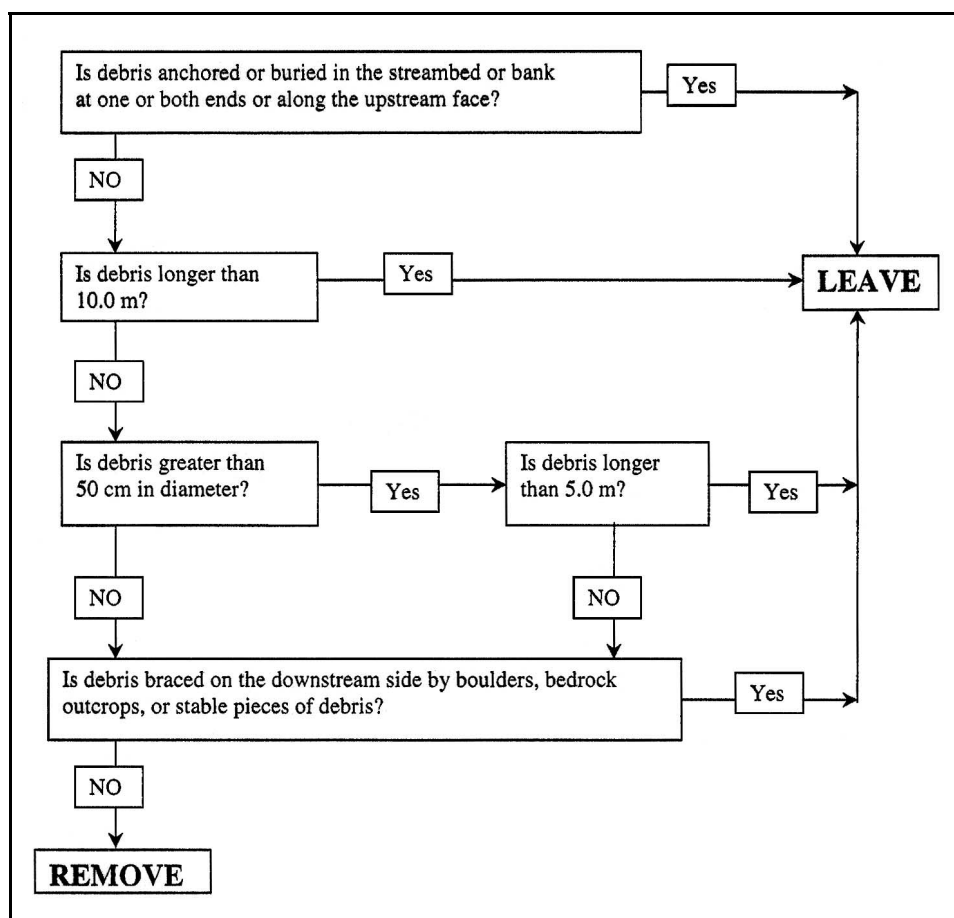


Figure 3-42. General large woody debris stability guide based on Salmon Creek, Washington (after Bilby, 1984).

Practices for Landings

- ☐ *Make landings no larger than necessary to safely and efficiently store logs and load trucks.*
- ☐ *Install drainage and erosion control structures as necessary.*

A slight slope on landings facilitates drainage. Also, adequate drainage on approach roads prevents road drainage water from entering the landing area.
- ☐ *Do not exceed 5 percent slope on the landing surface and shape it to promote efficient drainage.*
- ☐ *Do not exceed 40 percent slope on landing fills and do not incorporate woody or organic debris into fills.*
- ☐ *If landings are to be used during wet periods, protect the surface with a suitable material such as wooden matting or gravel surfacing.*

- ☐ *Install drainage structures for the landings such as water bars, culverts, and ditches to avoid sedimentation. Disperse landing drainage over side slopes. Provide filtration or settling if water is concentrated in a ditch.*
- ☐ *Upon completion of a harvest, clean up, regrade, and revegetate the landing.*
 - Upon abandonment, minimize erosion on landings by adequately ditching or mulching with forest litter.
 - Establish a herbaceous cover on areas that will be used again in repeated cutting cycles, and restock landings that will not be reused.
 - If necessary, install water bars for drainage control.
 - Landings should be ripped to break up compacted soil layers and allow water infiltration. This will also aid in the establishment of new vegetation.
 - Runoff on and from landings should be dispersed with waterbars or dips.
- ☐ *Locate landings for cable yarding where slope profiles provide favorable deflection conditions so that the yarding equipment used does not cause yarding corridor gouge or soil plowing, which concentrates drainage or causes slope instability.*
- ☐ *Locate cable yarding corridors for streamside management areas following the components of the Streamside Management Areas management measure. Avoid causing disturbance of the major channel banks of the watercourse of the SMA with yarded logs.*

Ground Skidding Practices

- ☐ *Skid uphill to log landings whenever possible. Skid with ends of logs raised to reduce rutting and gouging.*
- This practice disperses water on skid trails away from the landing. Skidding uphill lets water from trails flow onto progressively less-disturbed areas as it moves downslope, reducing erosion hazard. Skidding downhill concentrates surface runoff on lower slopes along skid trails, resulting in significant erosion and sedimentation hazard (Figure 3-43). If skidding downhill, provide adequate drainage on approach trails so that drainage does not enter the landing.
- ☐ *Skid along the contour (perpendicular to the slope), and avoid skidding on slopes greater than 40 percent.*

Following the contour reduces soil erosion and encourages revegetation. If skidding has to be done parallel to the slope, skid uphill, taking care to break the grade periodically.

Avoid skid trail layouts that concentrate runoff into draws, ephemeral drainages, or watercourses and avoid skidding up or down ephemeral drains. Use endlining to winch logs out of SMAs or directionally fell trees so tops extend out of SMAs and trees can be skidded without operating equipment in SMAs. In SMAs, endline trees carefully to avoid soil plowing or gouge.

Suspend ground skidding during wet periods, when excessive rutting and churning of the soil begins, or when runoff from skid trails is turbid and no longer infiltrates within a

short distance from the skid trail. Further limitation of ground skidding of logs, or use of cable yarding, might be needed on slopes where there are sensitive soils and/or during wet periods.

Retire skid trails by installing water bars or other erosion control and drainage devices, removing culverts, and revegetating.

- After logging, obliterate and stabilize all skid trails by mulching and reseeding.
- Build cross drains on abandoned skid trails to protect stream channels or side slopes in addition to mulching and seeding.
- Restore stream channels by removing temporary skid trail crossings.
- Distribute logging slash throughout skid trails to supplement water bars and seeding to reduce erosion on skid trails.

Cable Yarding Practices

- ☐ *Use cabling systems or other systems when ground skidding would expose excess mineral soil and induce erosion and sedimentation.*

- Use high-lead cable or skyline cable systems on slopes greater than 40 percent.
- To avoid soil disturbance from sidewash, use high-lead cable yarding on average-profile slopes of less than 15 percent.

- ☐ *Avoid cable yarding in or across watercourses.*

When cable yarding across streams cannot be avoided, use full suspension to minimize damage to channel banks and vegetation in the SMA. Cut or clear cableways across SMAs where SMAs must be crossed. This will reduce the damage to trees remaining and prevent trees next to the stream channel from being uprooted.

- ☐ *Yard logs uphill rather than downhill.*

When yarding uphill, log decks are placed on ridges or hilltops rather than in low-lying areas. This approach results in less soil disturbance for two reasons: (1) lifting the logs reduces their weight on the ground and thus the amount of friction and ground scouring, and (2) yard trails radiate outward from the elevated position of the log deck, dispersing runoff in numerous directions from the deck (Figure 3-43).

Downhill yarding does the opposite. The full weight of the logs is transferred to the ground, and runoff from all of the yard trails is directed downslope to the log deck, concentrating the erosive effect of rain. If yarding uphill is not possible, soil disturbance can be minimized during downhill yarding by suspending logs from a pulley system so that the logs are lifted partially or completely off the ground.

The amount of soil disturbance caused by yarding depends on the slope of the area, the volume yarded, the size of the logs, and the logging system. Megahan (1980) ranked yarding techniques (from greatest effect to lowest effect) based on percent area disturbed as follows: tractor (21 percent average), ground cable (21 percent, one study), high-lead (16 percent average), skyline (8 percent average), jammer in clear-cut (5 percent, one study), and aerial techniques (4 percent average). Aerial and skyline cable techniques are far less damaging than other yarding techniques.

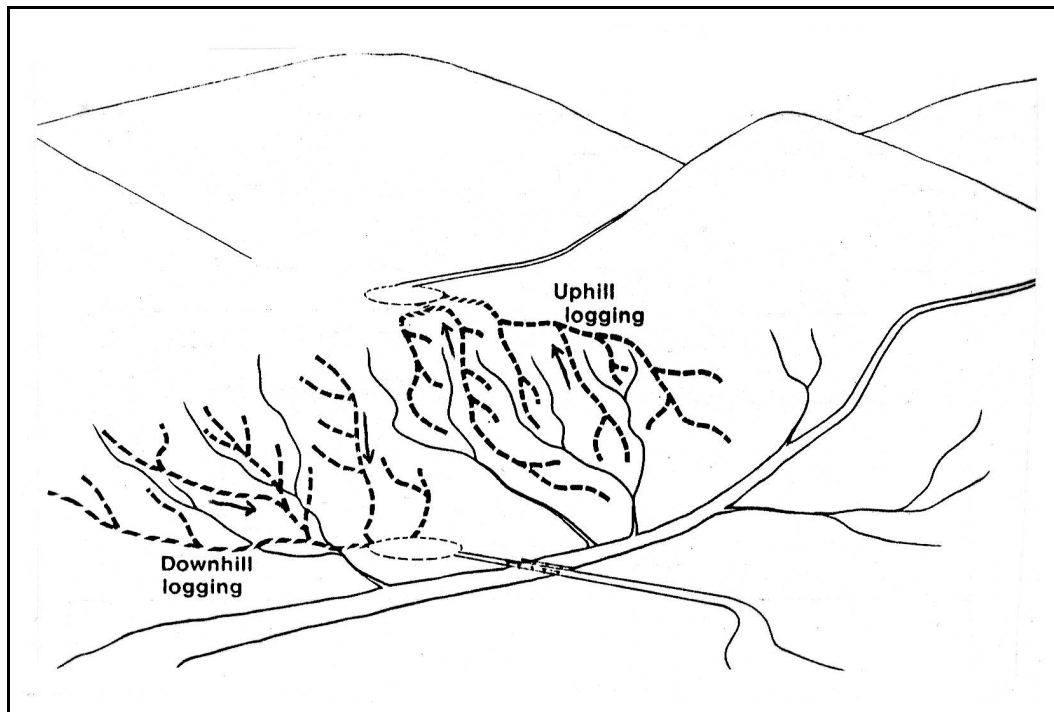


Figure 3-43. Hypothetical skid trail pattern for uphill and downhill logging (dashed lines). Logging uphill, water from tracks flows on to progressively less-disturbed areas as it moves downslope, reducing erosion hazard. Downhill logging concentrates surface runoff on the lower slopes along main skid tracks, causing a considerable erosion and sediment hazard (Megahan, 1983).

The amount of road needed for different yarding techniques varies considerably (Sidle, 1980). Skyline techniques use the least amount of road area, with only 2 to 3.5 percent of the land area in roads. Tractor and single-drum jammer techniques use the greatest amount of road area (10 to 15 percent and 18 to 24 percent of total area, respectively). High-lead cable techniques fall in the middle, with 6 to 10 percent of the land used for roads. Compared to the skyline and aerial techniques, tractor, jammer, and high-lead cable methods result in significantly higher amounts of disturbed soil (Megahan, 1980). Figure 3-44 shows a typical cable yarding operation (OSHA, 1999).

Other Yarding Methods

☐ *Helicopter yarding.*

Helicopter yarding is a practical and environmentally friendly alternative yarding approach for use on public and private timberlands where other yarding systems would be physically, economically, or environmentally infeasible. According to the Helicopter Logging Association (1998), the benefits of helicopter timber harvesting include:

- Minimum damage is caused to the following:
 - The soil layer. Very little vehicular traffic is associated with the method.
 - Water resources. There is a negligible increase in stream turbidity compared to conventional yarding methods.
 - Riparian areas.
 - Wildlife habitat.

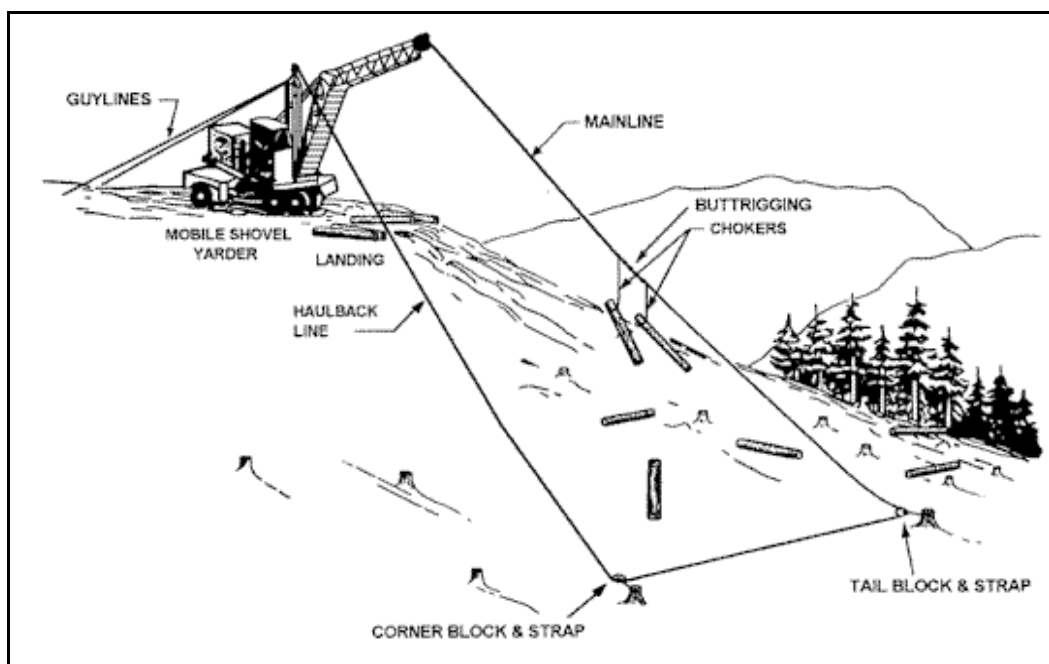


Figure 3-44. Typical cable yarding operation (OSHA, 1999).

- Damage to retained trees is reduced. Fewer trees are felled per acre and ground-based skidders are absent.
- Road density is lower. A combined helicopter and tractor logging approach can reduce road density by approximately half compared to conventional tractor methods. Environmental damage is thus reduced, and forest access points are fewer.

□ *Shovel harvesting.*

Shovel harvesting is more widely used in the coastal areas of the Pacific Northwest and the wetland areas of the Southeast than in other parts of the United States (Aust, Virginia Tech, personal communication, 2000).

The process of shovel harvesting involves a shovel logger moving in lines parallel to a road, picking up logs that have been felled by a logger and lifting debris out of gullies as it moves forward. The shoveler starts at the nearest access point and moves logs until they are within reach of a road, where they can be retrieved (Figure 3-45) (Humboldt State University, 1999).

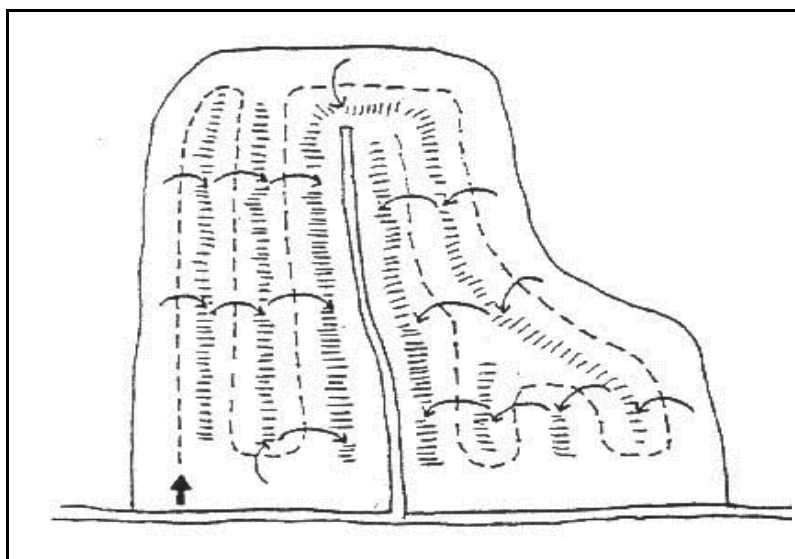


Figure 3-45. Common pattern of shovel logging operations (Humboldt State University, 1999).

Shovel logging is considered an environmentally friendly means to harvest timber. Operations require fewer people and fewer access roads, produce no skid trails, reduce ground disturbance in environmentally

sensitive areas such as wetlands, and disturb SMAs less than any conventional logging method. Table 3-31 compares the costs of various yarding methods.

Table 3-31. Costs Associated with Various Methods of Yarding.

| Yarding Method | Cost Range ^a |
|---------------------------------|--|
| Cable Yarding ^b | \$90 to \$135/ac, depending on yarding distance, crew size, and size of landing. <ul style="list-style-type: none"> • Clearcutting costs \$50 to \$60/mbf • Thinning costs \$200/mbf |
| Helicopter Yarding ^b | \$3,000 to \$3,500/hr; or \$180 to \$300/mbf \$175 to \$285/mbf |
| Shovel Harvesting | \$25.00 to \$83.84/hr |

^a Costs listed are for examples of use in the Pacific Northwest.

^b Dorn, 2000; Yoder, 2000

□ *Balloon harvesting.*

Balloon harvesting involves using hot air or helium balloons to remove logs from a harvest site for loading on trucks (Figure 3-46). Because the logs are lifted off the ground and taken to a log landing, they are not dragged up or down a slope and disturbance to the ground is reduced. In areas where road construction is expensive, balloon harvesting can save money and protect the environment because of the smaller number of roads and skid trails needed. The environmental benefits realized from balloon harvesting are similar to those associated with helicopter yarding. Additionally, balloon harvesting permits access to wet sites such as wetlands and steep slopes where ground skidding would not be feasible because of the potential for environmental damage or the cost of road construction (Aust, Virginia Tech, personal communication, 2000).

Winter Harvesting

Winter harvesting is a component of several state timber removal programs. In winter frozen ground provides conditions that do not exist during other times of the year for timber harvest activities and an opportunity for low-impact logging (Logan and Clinch, 1991). Areas where winter road construction and harvesting are particularly advantageous include wetlands (see subsection 3J, *Management Measure for Wetlands Forest Management* of this document for a discussion of BMPs specifically for wetland harvesting), sensitive riparian areas, and sites where erosion and soil compaction would be expected to be a serious problem during nonfrozen conditions.

BMP guidelines for warmer months apply during winter harvesting as well. Additional practices that can be implemented to ensure the protection of water quality include the following (Logan and Clinch, 1991; North Dakota Forestry Service, 1999):

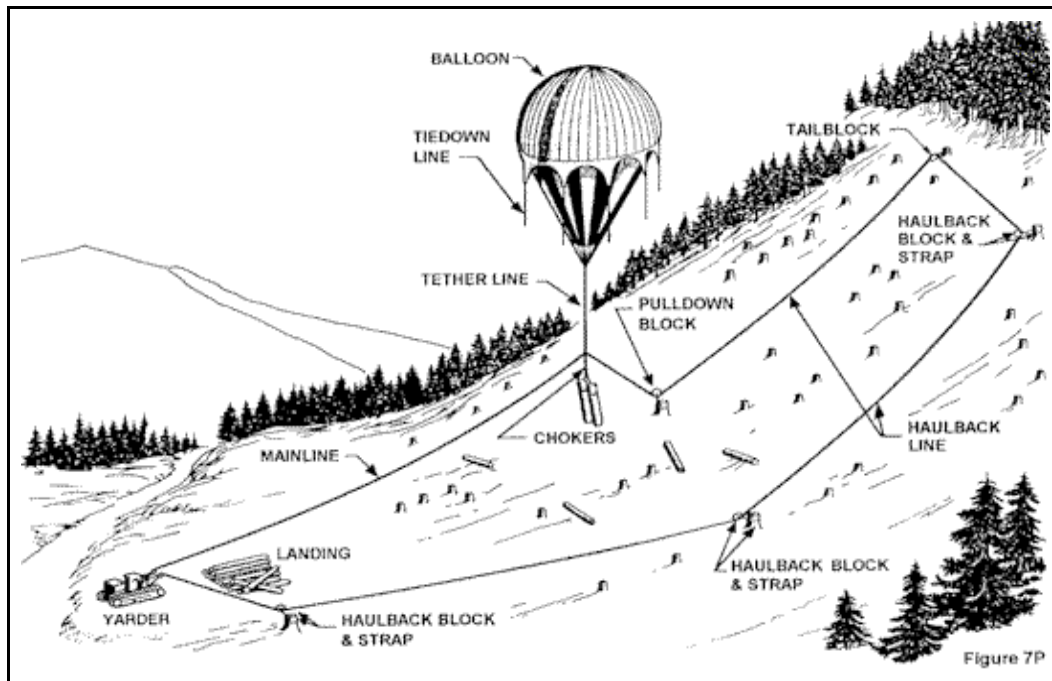


Figure 3-46. Balloon harvesting practices on a steep slope (OSHA, 1999).

- ☐ *Consult with operators experienced in winter logging techniques.*
- ☐ *Compact skid trail snow before skidding logs.*

Compacting the snow prevents damage to soils that are still wet or not completely frozen.

- ☐ *Avoid steeper areas where frozen skid trails may be subject to erosion the following spring.*
- ☐ *Before felling in wet, unfrozen soil areas, use tractors or skidders to compact the snow on skid trails. Avoid steep areas where frozen skid trails might be subject to erosion the following spring.*

Petroleum Management Practices

- ☐ *Service equipment where spilled fuel or oil will not reach watercourses, and drain all petroleum products and radiator water into containers.*
- ☐ *Dispose of wastes and containers in accordance with proper waste disposal procedures.*

Do not leave waste oil, filters, grease cartridges, and other petroleum-contaminated materials as refuse in the forest.

- ☐ *Take precautions to prevent leakage and spills.*

Ensure that fuel trucks and pickup-mounted fuel tanks do not have leaks. Use and maintain seepage pits or other confinement measures to prevent diesel oil, fuel oil, or

other liquids from running into streams or important aquifers, and use drip collectors on oil-transporting vehicles.

- ☐ *Develop a spill contingency plan that provides for immediate spill containment and cleanup, and notification of proper authorities.*

Have materials for absorbing spills easily accessible, and collect wastes for proper disposal.

3F: Site Preparation and Forest Regeneration

Management Measure for Site Preparation and Forest Regeneration

Confine on-site potential NPS pollution and erosion resulting from site preparation and the regeneration of forest stands. The components of the management measure for site preparation and regeneration are:

- (1) Select a method of site preparation and regeneration suitable for the site conditions.
- (2) Conduct mechanical tree planting and ground-disturbing site preparation activities on the contour of sloping terrain.
- (3) Do not conduct mechanical site preparation and mechanical tree planting in streamside management areas.
- (4) Protect surface waters from logging debris and slash material.
- (5) Suspend operations during wet periods if equipment used begins to cause excessive soil disturbance that will increase erosion.
- (6) Locate windrows at a safe distance from drainages and SMAs to control movement of the material during high-runoff conditions.
- (7) Conduct bedding operations in high-water-table areas during dry periods of the year. Conduct bedding in sloping areas on the contour.
- (8) Protect small ephemeral drainages when conducting mechanical tree planting.

Management Measure Description

Regeneration of harvested forestlands is important not only in terms of restocking a valuable resource, but also in terms of minimizing erosion and runoff from disturbed soils that could degrade water quality. Vegetative cover on disturbed soils reduces raindrop impact and slows storm runoff, and the roots of vegetation stabilize soils by holding them in place and aiding their aggregation. Both of these factors decrease erosion.

Harvesters and landowners can follow certain practices to protect the soil and aid tree regeneration. For instance, leaving the forest floor litter layer intact during site preparation operations minimizes soil disturbance and detachment, maintains infiltration, and slows runoff. These factors in turn reduce erosion and sedimentation after site preparation is completed. It is especially important to leave the forest floor litter layer intact in areas that have steep slopes, or erodible soils, or where the prepared site is located near a waterbody, all of which increase the risk of erosion, landslides, and degraded water quality. Site preparation methods such as herbicide application and prescribed burning cause less disturbance to the soil surface than mechanical practices and can be considered where mechanical site preparation could pose a threat to water quality. Drum chopping, a form of mechanical site preparation, normally results in less soil exposure than other mechanical methods. The intensity of a prescribed burn in part determines whether use of the method will pose a threat to water quality.

Natural regeneration, hand planting, and direct seeding are other methods that can be used to minimize soil disturbance, especially on steep slopes with erodible soils.

Mechanical planting with machines that scrape or plow the soil surface can produce erosion rills, increasing surface runoff and erosion and decreasing site productivity.

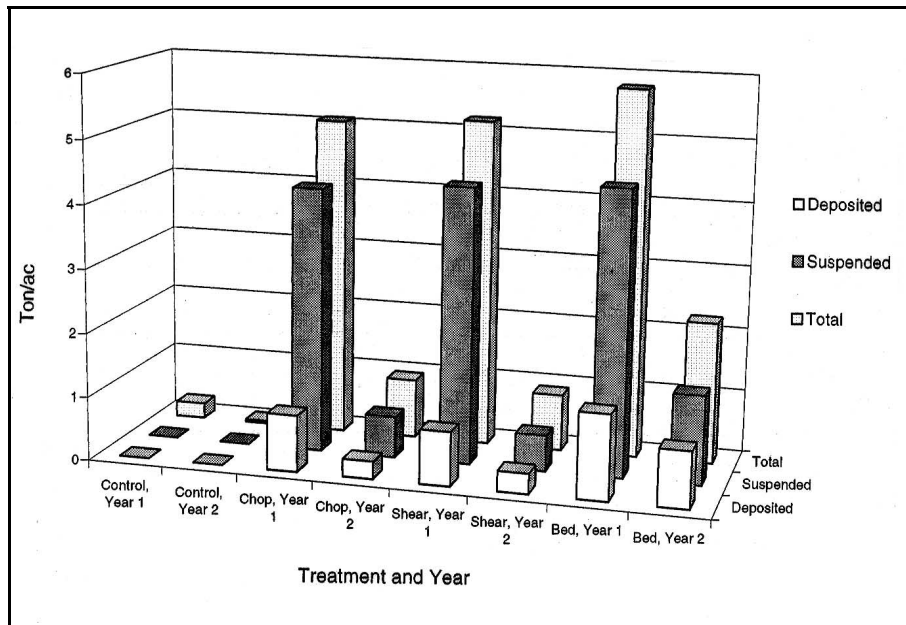


Figure 3-47. Deposited, suspended, and total sediment losses in experimental watersheds during water years 1976 and 1977 for various site preparation techniques (Mississippi, Arkansas) (Beasley, 1979).

Data in Figures 3-47 to 3-52 compare sediment loss or erosion rates for numerous site preparation methods. Many of the data are site-specific, so site characteristics and experimental conditions are mentioned (when available) in the text below and regional locations are noted on the figures.

Beasley (1979) studied the relative soil disturbance effects of site preparation following clearcutting on three small watersheds in the hilly northern coastal plain of Mississippi and Arkansas (Figure 3-47). Slopes in the three watersheds were mostly 30 percent or more.

One site was single drum-chopped and burned; another was sheared and windrowed (windrows were burned); and a third was sheared, windrowed, and bedded to contour. The control watershed was instrumented and left uncut. Soil exposure was 37 percent on the chopped site, 53 percent on the sheared and windrowed site, and 69 percent on the bedded site. A temporary cover crop of clover was sown after site preparation to protect the soil from rainfall impact and erosion. Increases in soil erosion and sediment

production were similar for all three treatments in the first year after site preparation. Decreases in these processes were noted during the second year on all sites. During the second year, the clover and other vegetation covered 85-95 percent of the surface of each site and effectively decreased sediment production.

Yoho (no date) compared sediment yields over a 2-year period from site preparation using chop and burn; shear, windrow, and burn; and shear, windrow, burn, and bed (Figure 3-48). Chop and burn produced the least amount of sediment in the second year. Site preparation using

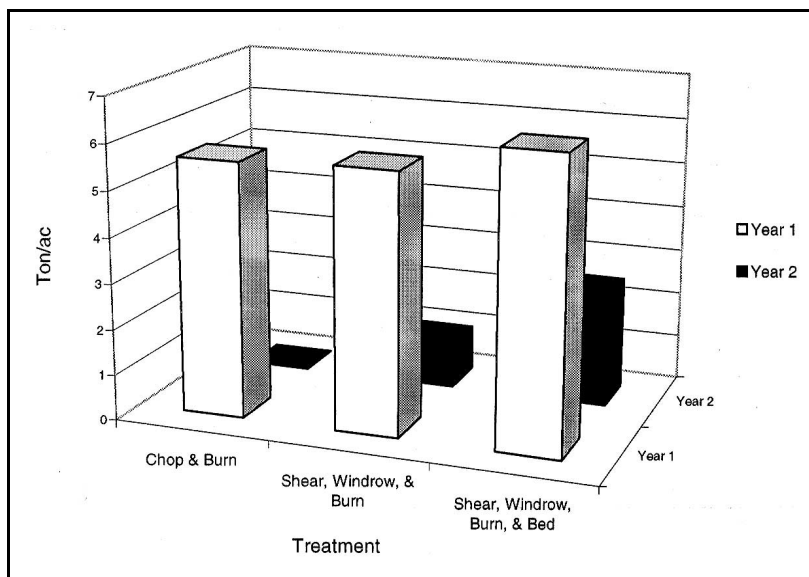


Figure 3-48. Comparison of sediment yields on three sites prepared using different techniques (Yoho, nd).

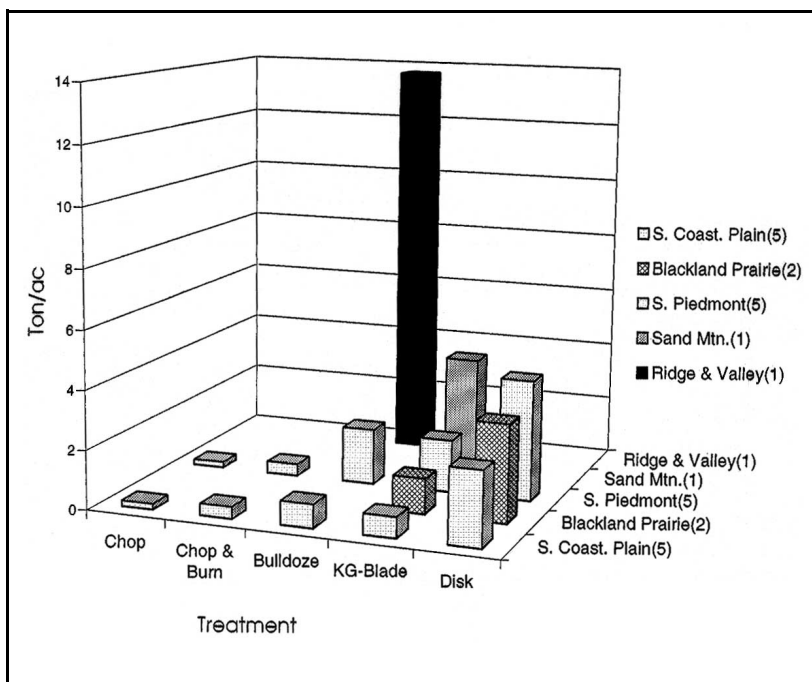


Figure 3-49. Predicted erosion rates using various site preparation techniques for physiographic regions in the southeastern United States (Golden et al., 1984). Numbers in parentheses indicate number of predictions for the region.

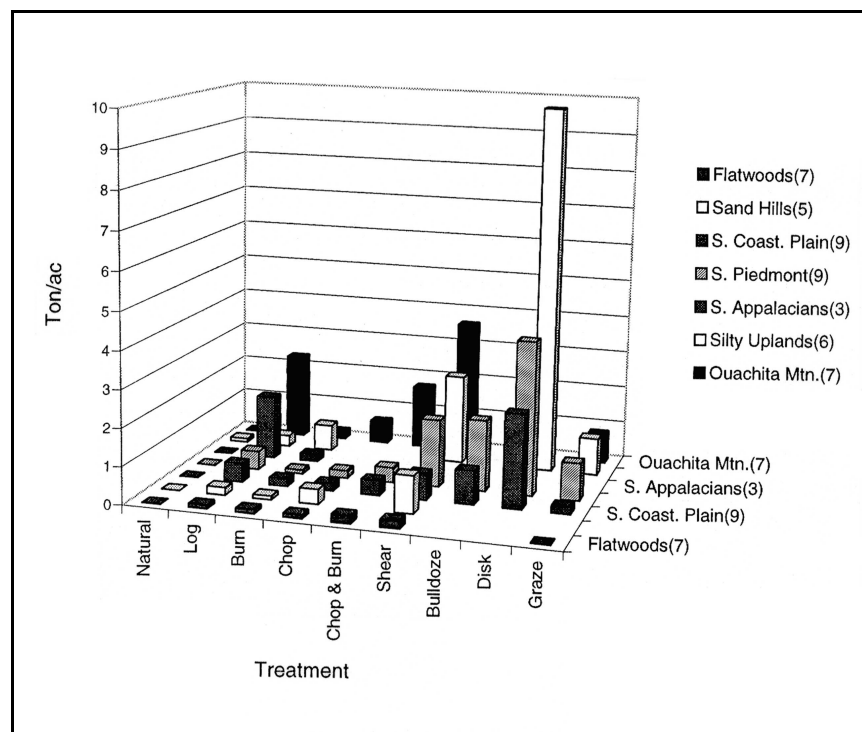


Figure 3-50. Erosion rates for site preparation practices in selected land resource areas in the Southeast (Dissmeyer, 1980). Numbers in parentheses indicate the number of sites in the region.

shearing, windrowing, burning, and bedding produced the highest second-year erosion rate, mostly due to channels formed between beds.

Golden and others (1984) summarized studies on erosion rates from site preparation (Figure 3-49). The rates reflect soil movement measured at the bottom of a slope, not the quantity of sediment actually reaching streams. Therefore, the numbers estimate the worst-case erosion if a stream is located directly at the toe of a slope with no intervening vegetation. Rates are averages for 3- to 4-year recovery periods.

Dissmeyer (1980) showed that disking produced more than twice the erosion rate of any other method (Figure 3-50).

Bulldozing, shearing, and sometimes grazing were associated with relatively high rates of erosion, and chopping or chopping and burning produced moderate erosion rates. Logging also produced moderate erosion rates in this study when the effect of skid and spur roads was included. The lowest rate of erosion was associated with burning.

Beasley and Granillo (1985) compared storm flow and sediment losses from mechanically and chemically prepared sites in southwest Arkansas over a 4-year period. Mechanical preparation (clearcutting followed by shearing, windrowing, and replanting with pine seedlings) increased sediment losses in the first 2 years after treatment. A subsequent decline in sediment

losses in the mechanically prepared watersheds was attributed to rapid growth of ground cover. Windrowing brush into ephemeral drainages and leaving it unburned effectively minimized soil losses by trapping sediment on the site and reducing channel scouring. Chemical site preparation (using herbicides) had no significant effect on sediment losses.

Blackburn and others (1982) studied water quality changes associated with two site preparation methods in Texas. Figure 3-51 shows that shearing and windrowing (which

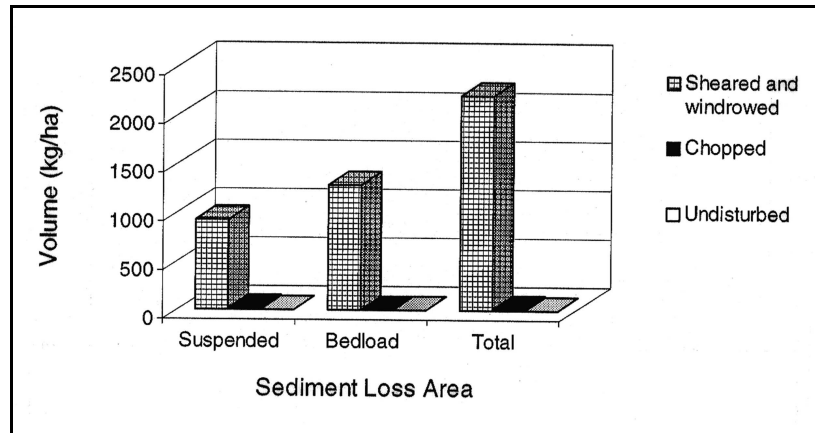


Figure 3-51. Sediment loss (kg/ha) in stormflow by site treatment from January 1 to August 31, 1981 (TX) (Blackburn et al., 1982).

exposed 59 percent of the soil) produced 400 times more sediment loading than chopping (which exposed 16 percent of the soil) during site preparation in this study. The authors also found that total nitrogen losses from sheared and windrowed watersheds were nearly 20 times greater than those from undisturbed watersheds and three times greater than those from chopped watersheds (Figure 3-52).

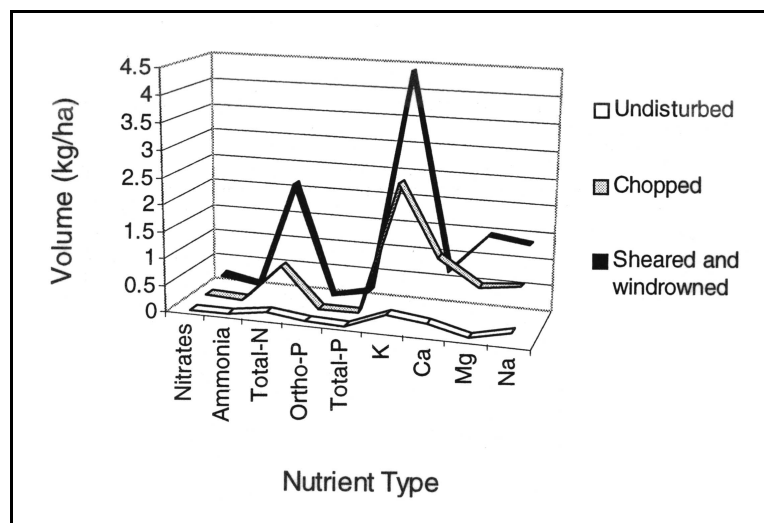


Figure 3-52. Nutrient loss (kg/ha) in stormflow by site treatment from January 1 to August 31, 1981 (TX) (Blackburn et al., 1982).

Mechanical Site Preparation in Wetlands

Under certain circumstances, a permit is needed for mechanical silvicultural site preparation activities when used for the establishment of pine plantations in the Southeast. EPA and the U.S. Army Corps of Engineers recently issued a memorandum to clarify the applicability of forested wetlands BMPs to these circumstances. Refer to the Wetlands Forest Management Measure for a discussion of permitting requirements in forested wetlands.

Benefits of Site Preparation Practices

Three studies summarized here compare the costs and benefits of different site preparation methods. Dissmeyer and Foster (1987) estimated the long-term costs and benefits of light and heavy site preparation in the Southeast. They concluded that light site preparation would yield more wood production and a higher internal rate of return on investment (Table 3-32). Heavy site preparation methods involve a greater initial investment than light site preparation methods but did not yield more wood per unit area.

Table 3-32. Analysis of Two Management Schedules Comparing Cost and Site Productivity in the Southeast (Dissmeyer and Foster, 1987).

| Year | Silviculture Treatment | Light Site Preparation ^a | | Heavy Site Preparation ^b | |
|--------------------------|-------------------------|-------------------------------------|-----------------------------------|-------------------------------------|-----------------------------------|
| | | Investment Per Hectare ^c | Wood Produced M ³ /ha | Investment Per Hectare ^c | Wood Produced M ³ /ha |
| 1984 | Site Prep/Tree Planting | \$297 | | \$420 | |
| 1999 | Thinning | \$252 | 64.2 pulpwood | \$180 | 46.0 pulpwood |
| 2010 | Thinning | \$256 | 22.3 saw timber 33.3 pulpwood | \$331 | 5.3 saw timber 22.0 pulpwood |
| 2020 | Final Harvest | \$2,422 | 133.5 saw timber 15.2 pulpwood | \$2,071 | 112.3 saw timber 22.0 pulpwood |
| Present Net Value (@ 4%) | | \$623 | | \$304 | |
| Internal Rate of Return | | 12.4% ^d | | 10.1% | |

Dissmeyer (1986) analyzed the economic benefits of controlling erosion during site preparation. Site preparation methods that increased soil exposure, displacement, and compaction increased site preparation costs and erosion from the site prepared (Table 3-33) and decreased timber production. Using light site preparation techniques such as a single chop and burn reduced erosion, increased timber production on the site, and cost less per unit area treated than more intensive site preparation methods. Heavy site preparation techniques such as shearing and windrowing removed nutrients, compacted soil, increased erosion and site preparation costs, and resulted in a lower present net value of timber.

Table 3-33. Site Preparation Comparison (VA, SC, NC) (Dissmeyer, 1986).

| Treatment | Treatment Cost (\$/acre) | Erosion Index ^a |
|----------------------------|--------------------------|----------------------------|
| No site preparation | \$59 | 1.0 |
| Burn only | \$67 | 1.1 |
| Single chop and burn | \$119 | 2.3 |
| Double chop and burn | \$178 | 3.0 |
| Single shear and burn | \$216 | 4.3 |
| Shear twice and burn | \$253 | 5.1 |
| Rootrake and disk and burn | \$253 | 16.0 |
| Rootrake and burn | \$253 | 16.0 |

The U.S. Forest Service (1987) examined the costs of three alternatives to slash treatment: (1) broadcast burn and protection of streamside management zones, (2) yarding of unmerchantable material (YUM) of 15 inches in diameter or more, and (3) YUM of 8 inches in diameter or more (Table 3-34). The two YUM alternatives cost approximately \$625-\$1,180/acre, in comparison to broadcast burning at \$1,300/acre (1998 dollars). In addition, the YUM alternatives protected highly erodible soils from direct rainfall and runoff effects, reduced fire hazards, resulted in meeting air and water quality standards, and allowed for the rapid establishment of seedlings on clearcut areas.

Table 3-34. Comparison of Costs for Yarding Unmerchantable Material (YUM) vs. Broadcast Burning (OR) (USDA-FS, 1987).

| Activity | Broadcast Burn and Protect SMA | YUM 15" in Diameter and No Burn | YUM 8" in Diameter and No Burn |
|-------------------------------------|--------------------------------|---------------------------------|--------------------------------|
| Broadcast burn | \$502/acre | N/A | N/A |
| SMA protection | \$646/acre | N/A | N/A |
| YUM, fell hardwood, lop and scatter | N/A | \$438/acre | \$1,004/acre |
| Planting cost | \$143/acre | \$187/acre | \$172/acre |
| Totals | \$1,291/acre | \$624/acre | \$1,177/acre |

All costs updated to 1998 dollars

Best Management Practices

Site Preparation Practices

- ☐ *Do not conduct mechanical site preparation, except for drum chopping, on slopes greater than 30 percent.*

On sloping terrain greater than 10 percent, or on highly erosive soils, operate mechanical site preparation equipment on the contour.

- ☐ *Do not conduct mechanical site preparation in SMAs.*
- ☐ *Do not place slash in perennial or intermittent drainages, and remove any slash that accidentally enters drainages.*

Slash can clog the channel and cause alterations in drainage configuration and increases in sedimentation. Extra organic material can lower the dissolved oxygen content of the stream. Slash also allows silt to accumulate in the drainage and to be carried into the stream during storm events.

- ☐ *Provide SMAs of sufficient width to protect streams from sedimentation by the 10-year storm.*
- ☐ *Locate windrows a safe distance from drainages to avoid material movement into the drainages during high-runoff conditions.*

Locating windrows above the 50-year floodplain usually prevents windrowed material from entering floodwaters.

- ☐ *Avoid mechanical site preparation operations during periods of saturated soil conditions, which might cause rutting and accelerate soil erosion.*
- ☐ *Minimize soil movement when shearing, piling, or raking.*
- ☐ *Minimize incorporation of soil material into windrows and piles during their construction.*

This can be accomplished by using a rake or, if using a blade is unavoidable, keeping the blade above the soil surface and removing only the slash. This helps retain nutrient-rich topsoil, which promotes rapid site recovery and tree growth and increases the effectiveness of the windrow in minimizing sedimentation.

Forest Regeneration Practices

- ☐ *Distribute seedlings evenly across the site.*
- ☐ *Order seedlings well in advance of planting time to ensure their availability.*
- ☐ *Hand plant highly erodible sites, steep slopes, and lands adjacent to stream channels (SMAs).*
- ☐ *Operate planting machines along the contour to avoid ditch formation.*
 - Ensure that soil conditions (slope, moisture conditions, etc.) are suitable for machine operation.
 - Close slits or drilling furrows periodically to avoid channeling flow.

3G: Fire Management

Management Measure for Fire Management

Prescribe fire for site preparation and control or suppress wildfire in a manner which reduces potential nonpoint source pollution of surface waters:

- (1) Intense prescribed fire should not cause excessive sedimentation due to the combined effect of removal of canopy species and the loss of soil-binding ability of subcanopy and herbaceous vegetation roots, especially in SMAs, in streamside vegetation for small ephemeral drainages, or on very steep slopes.
- (2) Prescriptions for prescribed fire should protect against excessive erosion or sedimentation to the extent practicable.
- (3) All bladed firelines, for prescribed fire and wildfire, should be plowed on contour or stabilized with water bars and/or other appropriate techniques if needed to control excessive sedimentation or erosion of the fireline.
- (4) Wildfire suppression and rehabilitation should consider possible NPS pollution of watercourses, while recognizing the safety and operational priorities of fighting wildfires.

Management Measure Description

The goal of this management measure is to minimize nonpoint source pollution and erosion resulting from prescribed fire used for site preparation, stand maintenance, and activities associated with wildfire control or suppression. Studies have shown that prescribed burning, if carefully planned and done using appropriate BMPs, has no significant effect on water quality (South Carolina Forestry Commission, 2000).

Prescribed burning reduces slash, competition for nutrients among seedlings, and fuel for wildfires. Where tree species are ecologically dependent on fire for regeneration, fire also serves as an essential forest management tool. Jack, lodgepole, and shortleaf pine are examples of species that depend to some extent on fire for successful regeneration. However, when slash burning is used as a site preparation tool it consumes vegetation that recycles nutrients into the soil. Additionally, improperly controlled burns can reach SMAs or highly erodible soils and lead to increased erosion, sedimentation, and an increase in stream temperature (through the loss of waterbody shading). Dyrness (1963) studied the effects of severe slash burning in the Pacific Northwest and found that it decreases soil porosity and infiltration capacity and increases the potential for soil erosion. Feller (1981) examined the effects of clearcutting alone and clearcutting with slash burning on stream temperatures in southwestern British Columbia. Both treatments increased summer temperatures as well as daily temperature fluctuations, and the effects lasted for 7 years in the clearcut stream and longer in the clearcut-with-slash burn stream. Clearcutting increased winter temperatures; slash burning decreased temperatures.

The intensity and severity of burning and the proportion of the watershed burned are the major factors that affect the influence of prescribed burning on streamflow and water quality. Fires that burn intensely on steep slopes close to streams and that remove most of the forest floor and litter down to the mineral soil are most likely to adversely affect

water quality. Stednick and others (1982) found increased concentrations of suspended sediments, phosphorus, and potassium in streamflows below the burned area after the slash burning of coastal hemlock-spruce forests of southeastern Alaska. Stream monitoring indicated an immediate flush of sediment and nutrients, followed by a slower release of these elements into surface water. No reduction in the nitrogen content or depth of the soil organic horizon was found, but there were significant reductions in the potassium and magnesium contents of the soil. The amount of erosion following a fire depends on:

- The amount of ground cover remaining on the soil
- The steepness of the slope
- The time, amount, and intensity of rainfall
- The intensity of fire
- The erodibility of the soil
- How rapidly a site revegetates

Periodic, low-intensity prescribed fires usually have little effect on water quality, and revegetation of burned areas reduces sediment yield from prescribed burning and wildfires.

Cost of Prescribed Burning

Costs associated with prescribed fire depend on the size of the fire crew, the amount of heavy equipment needed at the site to control the burn, the areal extent and intensity of the burn, and the topography of the area being burned. Table 3-35 provides a range of costs associated with prescribed burning (Hansit, personal communication, 2000; Holburg, personal communication, 2000).

Table 3-35. Range of Prescribed Fire Costs

| Topography | Crew Cost^a | Heavy Equipment Cost^a |
|-------------------|------------------------------|---|
| Mountainous | \$50 to \$100 per acre | \$200 to \$400 per acre |
| Flat land | \$3 to \$60 per acre | \$75 to \$300 per acre |

^a Hansit, personal communication, 2000; Holburg, personal communication, 2000.

Best Management Practices

Prescribed Fire Practices

- ☐ *Carefully plan burning to take into account weather, time of year, and fuel conditions so that these help achieve the desired results and minimize effects on water quality.*

Evaluate ground conditions to control the pattern and timing of the burn.

- ☐ *Do not conduct intense prescribed fire for site preparation in the SMA.*

- ☐ *Do not pile and burn for slash removal purposes in the SMA.*
- ☐ *Avoid construction of fire lines in the SMA or immediately adjacent or parallel to the SMA.*
- ☐ *Prescribe burns should be only as intense as necessary to achieve the desired objective. If possible, burn to maintain some of the duff or residual organic matter on the soil to prevent soil erosion.*
- ☐ *Avoid conditions that require extensive blading of fire lines by heavy equipment when prescribing burns.*
- ☐ *Use handlines, firebreaks, and hose lays to minimize blading of fire lines.*
- ☐ *Execute the burn with a trained crew and avoid intense burning.*

Intense burning can accelerate erosion by consuming the organic cover.

- ☐ *Avoid burning on steep slopes in high-erosion-hazard areas or areas that have highly erodible soils.*

Prescribed Fire in Wetlands

- ☐ *Conduct burns in wetlands in a manner that does not completely remove the organic layer of the forest floor.*

Prescribed burns conducted in wetlands are usually the most severe (hottest), removing most if not all of the forest floor organic layer. They therefore need to be carefully controlled to decrease the potential to increase surface runoff and soil erosion.

- ☐ *Do not construct firelines that could drain wetlands.*

Wildfire Practices

Wildfire and prescribed fire change erosion rates on the burned area in two ways. First, fire eliminates vegetative soil cover. Second, chemical changes in the soil following fire create an increased resistance to water infiltration in the upper soil layer, and this increases surface runoff and sheet erosion (Elliot et al., 1998). The magnitude of these effects depends on how hot a fire burns, and this in turn depends on numerous site characteristics. For instance, a fire burns more intensely on a high, sunny, and wind-dried slope than in a low, shaded, moist valley. Erosion following fire is most severe where a fire has burned most intensely and the fire is followed by a strong storm, a year of moderately high rainfall, or a spring with a large volume of snowmelt.

- ☐ *Whenever possible avoid using fire-retardant chemicals in SMAs and over watercourses, and prevent their runoff into watercourses. Do not clean application equipment in watercourses or locations that drain into watercourses.*
- ☐ *Close water wells excavated for wildfire-suppression activities as soon as practical following fire control.*

- ☐ *During wildfire emergencies, firelines, road construction, and stream crossings are unrestricted by BMPs. However, install BMPs and begin remediation as soon as possible after the emergency is controlled.*

Fireline Practices

Fireline construction is an integral part of both wildfire suppression and prescribed burning. Because of the possibility of water quality degradation following fireline construction, however, precautions are necessary to ensure that water quality is not impaired when firelines are constructed (Florida Department of Agriculture and Consumer Services, 1993). Fireline construction involves removing vegetation, and this can result in excessive erosion and water quality degradation. In wetland systems, firelines can function as drainage corridors, resulting in excessive drainage and converting a wetland to a non-wetland system. Implementation of one or more of the following practices can minimize water quality effects from fireline construction.

- ☐ *Use natural or in-place barriers (e.g., roads, streams, and lakes) to minimize the need for fireline construction in situations where artificial construction of firelines could result in excessive erosion and sedimentation.*
- ☐ *Avoid placing firelines through sensitive areas such as wetlands, marshes, prairies, and savannas unless absolutely necessary.*
- ☐ *When crossing waterbodies with plowing equipment, raise the plow to prevent connecting the fireline directly to the waterbody. Waterbodies can be used as firelines to avoid unnecessarily disturbing riparian zones.*
- ☐ *Construct firelines in a manner that minimizes erosion and sedimentation and prevents runoff from directly entering watercourses.*
 - Locate firelines on the contour whenever possible, and avoid straight uphill-downhill placement.
 - Install grades, ditches, and water bars while the line is being constructed.
 - Install water bars on any fireline running up and down the slope, and direct runoff onto a filter strip or sideslope, not into a drainage.
 - Construct firelines at a grade of 10 percent or less where possible.
 - Adequately cross-ditch all firelines at the time of construction.
 - Construct simple diversion ditches or turnouts on firelines at intervals as needed to direct surface water off the plowed line and onto undisturbed forest cover for dispersion of water and soil particles.
 - Construct firelines only as deep and wide as necessary to control the spread of the fire.
- ☐ *Where possible, use alternatives to plowed lines such as harrowing, foam lines, wet lines, or permanent grass.*
- ☐ *Get live cover on the site as soon as possible to maintain erosion control measures on firelines after the burn.*
- ☐ *Revegetate firelines with adapted herbaceous species.*

Refer to the Management Measure for Revegetation of Disturbed Areas for more

detailed information about this practice.

- ☐ *Execute the burn with a trained crew and avoid intense burning.*

Intense burning can accelerate erosion by consuming the organic cover.

- ☐ *Avoid burning on steep slopes in high-erosion-hazard areas or areas that have highly erodible soils.*

3H: Revegetation of Disturbed Areas

Management Measure for Revegetation of Disturbed Areas

Reduce erosion and sedimentation by rapid revegetation of areas disturbed by harvesting operations or road construction:

- (1) Revegetate disturbed areas (using seeding or planting) promptly after completion of the earth-disturbing activity. Local growing conditions will dictate the timing for establishment of vegetative cover.
- (2) Use mixes of species and treatments developed and tailored for successful vegetation establishment for the region or area.
- (3) Concentrate revegetation efforts initially on priority areas such as disturbed areas in SMAs or the steepest areas of disturbance (e.g., on roads, landings, or skid trails) near drainages.

Management Measure Description

Revegetating disturbed areas restabilizes the soil in these areas, reduces erosion, and helps to prevent sediment and pollutants associated with sediment (such as phosphorus and nitrogen) from entering into nearby surface waters. Vegetation controls soil erosion

by dissipating the impact force of raindrops, reducing the velocity of surface runoff, trapping dry sediment and preventing it from moving farther downslope, stabilizing the soil with roots, and contributing organic matter to the soil, which increases soil infiltration rates.

Nutrient and soil losses to streams and lakes are reduced by revegetating harvested, burned, or other disturbed areas. In some cases, planting early to establish erosion protection quickly and then again later to provide more permanent protection is necessary and advisable to prevent excessive erosion.

Good ground cover is key to reducing erosion. Figure 3-53 illustrates demonstrates the relationship between percent ground cover and slope and the resulting soil loss. Good ground cover is defined as *living plants within 5 feet of the ground and litter or duff with a depth of 2 inches or more* (Kuehn and Cobourn, 1989).

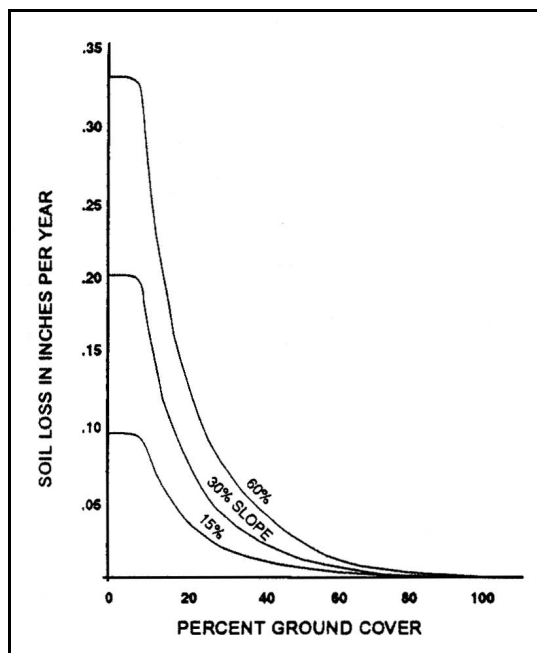


Figure 3-53. Relation of soil loss to ground cover (Kuehn and Cobourn, 1989).

Benefits and Costs of Revegetation Practices

The effectiveness of revegetation for controlling erosion, particularly on steep slopes and road fills, depends on protecting the slope until vegetative growth can take hold and grow enough to serve as a soil stabilizer. Straw mulch and netting are common ways to protect a newly seeded and fertilized slope. Adding straw mulch can reduce erosion by one-eighth to one-half.

Adding netting with mulch can reduce erosion by nearly 100 percent to negligible levels (Figure 3-54) (Bethlahmy and Kidd, 1966).

Megahan (1987) estimated that the cost of seeding with plastic netting placed over the seeded area (approximately \$8,200 per acre) is almost 50 times more than the cost of dry seeding alone (approximately \$180 per acre). Other cost estimates related to practices for forest regeneration are presented in Tables 3-36 to 3-38. Dubensky (1991) estimated

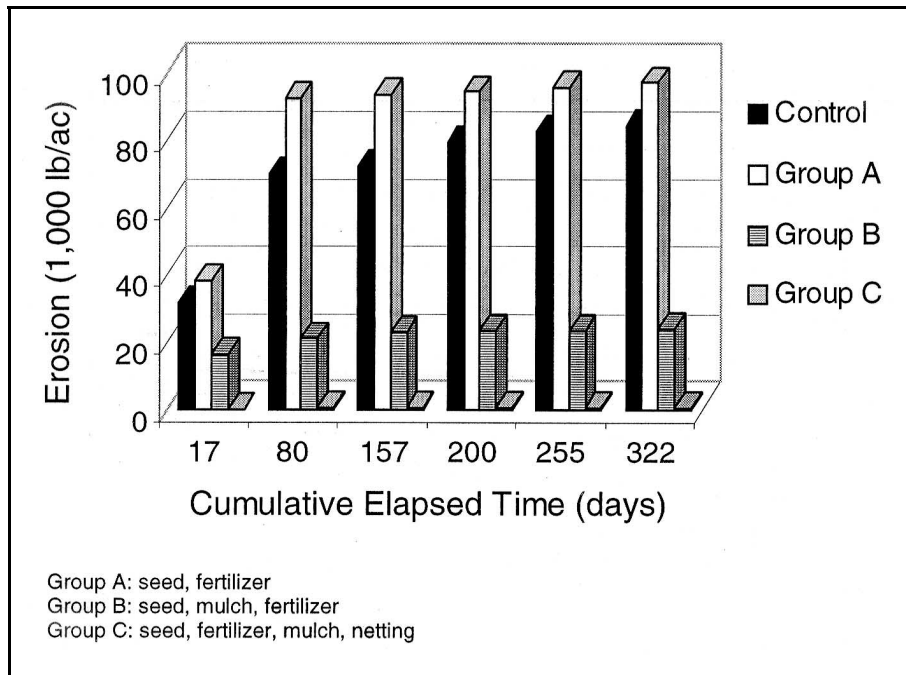


Figure 3-54. Comparison of the effectiveness of seed, fertilizer, mulch, and netting in controlling cumulative erosion from treated plots on a steep road fill in Idaho (Bethlahmy and Kidd, 1966).

Table 3-36. Economic Effect of Implementation of Proposed Management Measures on Road Construction and Maintenance (Dubensky, 1991)^a.

| Management Practice | Increased Cost |
|---|----------------|
| Fiber for road and landing construction/maintenance | \$5.00/ton |
| Ripping, shaping, and seeding log decks | \$214/deck |
| Seeding firelines or rough logging roads | \$24/100 ft |
| Construction and seeding of water bars | \$15 each |
| Construction of rolling dips on roads | \$24 each |

All costs updated to 1998 dollars

^aPublic comment information provided by the American Paper Institute and the National Forest Products Association.

Table 3-37. Cost Estimates (and Cost as a Percent of Gross Revenues) for Seed, Fertilizer, and Mulch (1987 Dollars) (Lickwar, 1989).

| Practice Component | Steep Sites ^a | Moderate Sites ^b | Flat Sites ^c |
|-----------------------------|--------------------------|-----------------------------|-------------------------|
| Seed, fertilizer, and mulch | \$19,950 (3.41%) | \$18,438 (2.72%) | \$17,590 (1.36%) |

All costs updated to 1998 dollars

^a Based on a 1,148-acre forest and gross harvest revenues of \$399,685. Slopes average over 9 percent.

^b Based on a 1,104-acre forest and gross harvest revenues of \$473,182. Slopes ranged from 4 percent to 8 percent.

^c Based on a 1,832-acre forest and gross harvest revenues of \$899,491. Slopes ranged from 0 percent to 3 percent.

Table 3-38. Estimated Costs for Revegetation (1991 Costs) (Minnesota DNR, 1991).

| Practice | Total Cost ^a |
|---|-------------------------|
| Establishment of permanent vegetative cover (includes seedbed preparation, fertilizer, chemicals and application, seed, and seeding as prescribed in the plan) | |
| Introduced grasses | \$96/acre |
| Native grasses | \$176/acre |

All costs updated to 1998 dollars

^a The costs shown represent the total cost of the practice. Calculations were made by dividing the maximum Federal cost share by 0.75 to obtain the total cost.

the economic effect of regeneration practices on the overall cost of a harvesting operation (Table 3-36). Lickwar (1989) compared revegetation costs for disturbed areas of various slope gradients in the Southeast (Table 3-37). Minnesota's Stewardship Incentives Program estimated the costs of reestablishing permanent vegetation with native and introduced grasses (Table 3-38).

Best Management Practices

- *Use mixtures of seeds adapted to the site, and avoid the use of exotic species. Choose annuals to allow natural revegetation of native understory plants, and select species that have adequate soil-binding properties.*

The selection of appropriate grasses and legumes is important for vegetation establishment. Grasses vary as to climatic adaptability, soil chemistry, and plant growth characteristics. USDA Natural Resources Conservation Service technical guides at the statewide level are excellent sources of information about seeding mixtures and planting prescriptions. The U.S. Forest Service, state foresters, and county extension agents can also provide helpful suggestions.

Using native species is both important and practical, and plenty of hardy native species are usually available. Nonnative species can outcompete and eliminate native vegetation, and the use of nonnative species often results in increased maintenance activities and expense.

Seeding rates (e.g., pounds per 1,000 square feet) are generally recommended for individual seed varieties and seed mixtures. Following such recommendations usually provides adequate cover and soil protection, whereas overseeding can create seedling overcrowding and subsequent failure.

- ☐ *On steep slopes, use native woody plants planted in rows, cordons, or wattles.*

These species may be established more effectively than grass and are preferable for binding soils.

- ☐ *Seed as soon as practicable after soil disturbance, preferably before rain, to increase the chance of successful vegetation establishment.*

Timing depends on the species to be planted and the schedule of operations, which determines when protection is needed.

- ☐ *Mulch as needed to hold seed, retard rainfall impact, and preserve soil moisture.*

Critical, first-year mulch applications provide the necessary ground cover to curb erosion and aid plant establishment. Various materials, including straw, bark, and wood chips, can be used to temporarily stabilize fill slopes and other disturbed areas and to improve conditions for germination immediately after construction. In most cases, mulching is

done together with seeding and planting to establish stable banks. Both the type and the amount of mulch applied vary considerably between regions and depend on the extent of the erosion potential and the available materials (Hynson et al., 1982). Figure 3-55 summarizes the effectiveness of various types of mulch (including Portland cement) for reducing erosion.

- ☐ *Fertilize according to site-specific conditions.*

Fertilization is often necessary for successful grass establishment because road construction commonly results in the removal or burial of fertile topsoil. To determine fertilizer formulations, it is best to compare available nitrogen, phosphorus, potassium, and sulphur in the soils to be treated with the requirements of the species to be sown. It might be necessary to refertilize periodically after vegetation

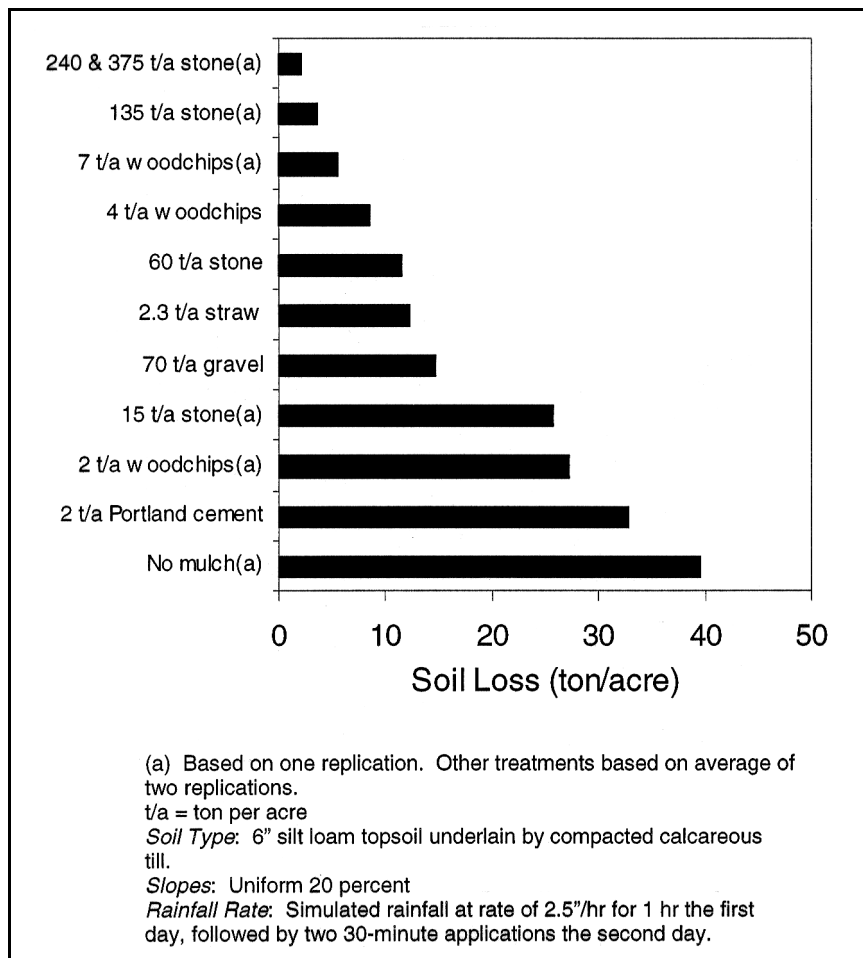


Figure 3-55. Soil losses from a 35-foot-long slope (Hynson et al., 1972).

establishment to maintain growth and erosion control capabilities. Fertilizer and other chemical management techniques are covered indepth in section 3I of the document.

- ☐ *Use biosolids as an alternative to commercial fertilizers.*

Biosolids is the name given to the solid material remaining after raw sewage has been treated. Biosolids can be used for forest regeneration efforts as a viable alternative to using commercial fertilizers. Biosolids are rich in nitrogen, as well as other nutrients essential for plant growth, including phosphorus, zinc, boron, manganese, and chromium (King County, Washington, 1999). The nutrients in biosolids are mostly in an organic form, so the biosolids act like a slow-release fertilizer, releasing only 15-20 percent of their nutrients during the first year after an application (Meyers, 1998). They also have a high content of organic matter, which increases soil infiltration rates and helps improve the ability of the soil to retain water, making it available for trees during dry periods. Biosolids can increase the growth rate of trees growing on relatively infertile soils to match that of trees growing on fertile soils.

Biosolids that are applied to the forest are treated at a wastewater treatment plant and then delivered to the forest as a semisolid product with a content of approximately 20 percent solids and 80 percent water. The biosolids can be dispersed onto the area to be treated using a device that throws them over the area, or they can be applied using a high-pressure hose. From a single point, they can be spread to a 250-foot radius or more where tree growth is still to be established or in young tree plantations, and to a 60-foot radius in thinned timber stands.

The number of tons of biosolids to be applied to each acre can be determined based on the nitrogen content of the biosolids. Specific amounts of nitrogen can be specified for each area to be treated based on soil testing and the nutrient requirements of the species being planted. In the Northwest, application rates vary from 3 dry tons/acre of biosolids for timber to 7 dry tons/ac for young plantations, which corresponds to 150 to 350 pounds of plant-available nitrogen per acre (King County, Washington, 1999).

Streams and other waterbodies are protected during biosolids applications by buffer areas that are not fertilized. Consult federal and state rules for minimum buffer area width for surface water protection. States regulate the use and application of biosolids, and obtaining a permit is usually necessary before biosolids may be used.

The potential for long-term effects from metals in biosolids has been raised as a concern, but biosolids that have very low levels of metals and meet EPA and state standards for use on food crops pose very little environmental threat (King County, Washington, 1999).

- ☐ *Protect seeded areas from grazing and vehicle damage until plants are well established.*
- ☐ *Inspect all seeded areas for failures, and make necessary repairs and reseed within the planting season.*
- ☐ *During non-growing seasons, apply interim surface stabilization methods to control surface erosion.*

Possible methods include mulching (without seeding) and installation of commercially produced matting and blankets. Alternative methods for planting and seeding include hand operations, the use of a wide variety of mechanical seeders, and hydroseeding.

3I: Forest Chemical Management

Forest Chemical Management

Use chemicals when necessary for forest management in accordance with the following to reduce nonpoint source pollution effects due to the movement of forest chemicals off-site during and after application:

- (1) Conduct applications by skilled and, where required, licensed applicators according to the registered use, with special consideration given to effects to nearby surface waters.
- (2) Carefully prescribe the type and amount of pesticides appropriate for the insect, fungus, or herbaceous species.
- (3) Prior to applications of pesticides and fertilizers, inspect the mixing and loading process and the calibration of equipment, and identify the appropriate weather conditions, the spray area, and buffer areas for surface waters.
- (4) Establish and identify buffer areas for surface waters. (This is especially important for aerial applications.)
- (5) Immediately report accidental spills of pesticides or fertilizers into surface waters to the appropriate state agency. Develop an effective spill contingency plan to contain spills.

Management Measure Description

Chemicals used in forest management are generally pesticides (insecticides, herbicides, and fungicides) and fertilizers. Since pesticides can be toxic, they have to be mixed, transported, loaded, and applied correctly and their containers disposed of properly to prevent potential nonpoint source pollution. Since fertilizers can also be toxic or can shift the ecosystem's energy dynamics, depending on the exposure and concentration, it is important that they be handled and applied properly.

Pesticides and fertilizers are occasionally introduced into forests to reduce mortality of desired tree species, improve forest production, and favor particular plant species. Many forest stands or sites never receive chemical treatment, and for those that do receive treatment, typically no more than two or three applications are made during an entire tree rotation (40 to 120 years).

Even though a limited number of applications might be made at a specific stand, in watersheds where many forest sites receive applications pesticides can accumulate in soils and in waterbodies. Application technique also partly determines the potential risk to the aquatic environment from infrequent applications of pesticides and fertilizers. These chemicals can directly enter surface waters through five major pathways—direct application, drift, mobilization in ephemeral streams, overland flow, and leaching. Direct application is the most important source of increased chemical concentrations and is also one of the most easily controlled.

Norris and others (1991) compiled information from multiple studies that evaluated the peak concentrations of herbicides, insecticides, and fertilizers in soils, lakes, and streams (Table 3-39). These studies were conducted from 1967 to 1987. Norris (1968) found

Table 3-39. Peak Concentrations of Forest Chemicals in Soils, Lakes, and Streams After Application (Norris et al., 1991).

| Chemicals ^a and System ^b | Application Rate (kg/hectare) | Concentration (mg/L or mg/kg*) | | Time Interval ^c | Time to Non- detection | Source ^d |
|---|-------------------------------------|-----------------------------------|------------|-------------------------------|------------------------------|---------------------|
| | | Peak | Subsequent | | | |
| Herbicides | | | | | | |
| 2,4-D | 2.24 | 0.001-0.13 | | | 1-168 h ^e | 17 |
| Marsh | 2.24 | 0.09 | | | | 17,18 |
| 2,4-D BE | | | | | | |
| Built pond | 23.0 | | | | | 1 |
| Water | | 3.0 | 1.0 | 85 d | | |
| | | | 0.2 | 180 d | | |
| Sediment | | 8.0* | 4.0* | 13+ d | | |
| | | | 0.4-0.6* | 82-182 d | | |
| Aquatic plants | | | 206* | 7 d | | |
| | | | 8* | 82 d | 182 d | |
| 2,4-D AS | | | | | | |
| Reservoir | | 3.6 | 0 | 13 d | | 7 |
| Picloram | | | | | | |
| Runoff | | 0.078 | | | | 19 |
| Runoff | | 0.038 | | | | 23 |
| Ephemeral stream | 2.8 | 0.32 | | 157 d | 915 d | 9 |
| Stream | 0.37 | | | | | 3 |
| Hexazinone | | | | | | |
| Stream (GA) | 1.68 | 0.044 | | 3-4 m | | 11 |
| Forest (GA) | 1.68 | | | | | 14 |
| Litter | | 0.177* | <0.01* | 60+ d | | |
| Soil | | 0.108* | <0.01* | 90 d | | |
| Ephemeral stream | | 0.514 | | 3 d | | |
| Perennial stream | | 0.442 | | 3 d | | |
| Atrazine | | | | | | |
| Stream | 3.0 | 0.42 | 0.02 | 17 d | | 16 |
| Built ponds | | | | | | 10 |
| Water | | 0.50 | 0.05 | 14 d | | |
| | | | 0.005 | 56 d | | |
| Sediments | | 0.50* | 0.9* | 4 d | | |
| | | 0.50* | 0.25* | 56 d | | |
| Triclopyr | | | | | | |
| Pasture (OR) | 3.34 | 0.095* | 0.09 | 5.5 h | | 20 |
| Glyphosate | | | | | | |
| Water | 3.3 | 0.27 | <0.01 | 3 d | | 15 |
| Dalapon | | | | | | |
| Field irrigation water | | 0.023-3.65 | <0.01 | Sev h | | 5 |

Table 3-39. (cont.)

| Chemicals ^a and System ^b | Application Rate (kg/hectare) | Concentration (mg/L or mg/kg*) | | Time Interval ^c | Time to Non- detection | Source ^d |
|---|-------------------------------------|-----------------------------------|-------------|-------------------------------|------------------------------|---------------------|
| | | Peak | Subsequent | | | |
| Insecticides | | | | | | |
| Malathion | | | | | | |
| Streams | 0.91 | | | | | 24 |
| Unbuffered | | 0.037-0.042 | | | | |
| Buffered | | 0-0.017 | | | | |
| Carbaryl | | | | | | |
| Streams & ponds (E) | | 0-0.03 | | | | 24 |
| Streams, unbuffered (PNW) | | 0.005-0.011 | | | 48 h | 24 |
| Water | 0.84 | 0.026-0.042 | | | | 8 |
| Brooks with buffer | 0.84 | 0.001-0.008 | | | | 22 |
| Rivers with buffer | 0.84 | 0.000-0.002 | | | | 22 |
| Streams, unbuffered | 0.84 | 0.016 | | | | 22 |
| Ponds | 0.84 | | | | | 6 |
| Water | | 0.254 | | | 100-400 d | |
| Sediment | | <0.01-5.0* ^f | | | | |
| Acephate | | | | | | |
| Streams | | 0.003-0.961 | | 1 d | | 4 |
| Pond sediment & fish | 0.56 | 0.113-0.135 | 0.013-0.065 | 14 d | | 21 |
| Fertilizers | | | | | | |
| Urea | 224 | | | | | |
| Urea-N | | | | | | |
| Forest stream (OR) | | 0.39 | 0.39 | 48 h | | 12 |
| Dollar Cr (WA) | | 44.4 | | | | 13 |
| NH ₄ ⁺ -N | | | | | | |
| Forest stream (OR) | | <0.10 | | | | 12 |
| Tahuya Cr (WA) | | 1.4 | | | | 13 |
| NO ₃ ⁺ -N | | | | | | |
| Forest stream (OR) | | 0.168 | | | | 12 |
| Elochoman R (WA) | | 4.0 | | | | 13 |

^a 2,4-D BE = 2,4-D butoxyethanol ester; 2,4-D AS = 2,4-D amine salt + ester.

^b E = eastern USA; Cr = Creek; GA = Georgia; PNW = Pacific Northwest; OR = Oregon; R = River; WA = Washington; buffer = wooded riparian strip.

^c d = day; h = hours; m = months; sev h = several hours. Intervals are times from application to measurement of peak or subsequent concentration, whichever is the last measurement indicated.

^d 1 = Birmingham and Colman (1985); 2 = Bocsor and O'Connor (1975); 3 = Davis et al. (1968); 4 = Flavell et al. (1977); 5 = Frank et al. (1970); 6 = Gibbs et al. (1984); 7 = Hoeppel and Westerdahl (1983); 8 = Hulbert (1978); 9 = Johnsen (1980); 10 = Maier-Bode (1972); 11 = Mayack et al. (1982); 12 = Moore (1970); 13 = Moore (1975b); 14 = Neary et al. (1983); 15 = Newton et al. (1984); 16 = M. Newton (Oregon State University, personal communication, 1967); 17 = Norris (1967); 18 = Norris (1968); 19 = Norris (1969); 20 = Norris et al. (1987); 21 = Rabeni and Stanley (1979); 22 = Stanley and Trial (1980); 23 = Suffling et al. (1974); 24 = Tracy et al. (1977).

^e Normally less than 48 h.

^f One extreme case: 23.8 mg/kg peak concentration, 16 months to nondetection.

that application of 2,4-D to marshy areas led to higher-than-normal levels of stream contamination. When ephemeral streams were treated, residue levels of hexazinone and picloram greatly increased with storm-generated flow. Glyphosate was aerially applied (3.3 kg/hectare) to an 8-hectare forest ecosystem in the Oregon Coast Range. The study area contained two ponds and a small perennial stream. All were unbuffered and received direct application of the herbicide. Glyphosate residues were detected for 55 days after application with peak stream concentrations of 0.27 mg/L. It was demonstrated that the concentration of insecticides in streams was significantly greater when the chemicals were applied without a buffer strip to protect the watercourse. When streams were unbuffered, the peak concentrations of malathion ranged from 0.037 to

0.042 mg/L. When buffers were provided, however, the concentrations of malathion were reduced to levels that ranged from undetectable to 0.017 mg/L. The peak concentrations of carbaryl ranged from 0.000 to 0.0008 mg/L when watercourses were protected with a buffer, but they increased to 0.016 mg/L when watercourses were unbuffered.

Moore (1971), as cited in Norris et al. (1991), compared nitrogen loss from a watershed treated with 224 kg urea-N per hectare to nitrogen loss from an untreated watershed. The study demonstrated that the loss of nitrogen from the fertilized watershed was 28.02 kg/hectare whereas the loss of nitrogen from the unfertilized watershed was only 2.15 kg/hectare (Table 3-40).

Table 3-40. Nitrogen Losses from Two Subwatersheds in the Umpqua Experimental Watershed (OR) (Norris et al., 1991).

| Loss Locus or Statistic | Urea-N | NH ₃ -N | NO ₃ -N | Total |
|-----------------------------------|--------|--------------------|--------------------|--------|
| Absolute loss (kg/hectare) | | | | |
| Watershed 2 (treated) | 0.65 | 0.28 | 27.09 | 28.02 |
| Watershed 4 (untreated) | 0.02 | 0.06 | 2.07 | 2.15 |
| Net loss (2-4) | 0.63 | 0.22 | 25.02 | 25.87 |
| Proportional loss | | | | |
| Percent of total | 2.44 | 0.85 | 96.71 | 100.00 |

Most adverse water quality effects related to the application of pesticides and fertilizers result from direct application of chemicals to surface waters or from chemical spills. Riekerk and others (1989) found that the greatest risk to water quality from pesticide application in forestry operations occurs from aerial application because of drift, wash-off, and erosion processes. They found that aerial applications of herbicides resulted in surface runoff concentrations roughly 3.5 times greater than those for application on the ground. The study results also suggested that tree injection application methods would be considered the least hazardous for water pollution, but would also be the most labor-intensive. Hand application of herbicides usually poses little or no threat to water quality in areas where there is no potential for herbicides to wash into watercourses through gullies. Providing buffer areas around streams and waterbodies can effectively eliminate adverse water quality effects from forestry chemicals.

Megahan (1980) summarized data on changes in water quality following the fertilization of various forest stands with urea. The major observations from this research are summarized below:

- Increases in the concentration of urea-N ranged from very low to a maximum of 44 ppm, with the highest concentrations attributed to direct application to water surfaces.
- Higher concentrations occurred in areas where buffer strips were not left beside streambanks.
- Chemical concentrations of urea and its by-products tended to be relatively short-lived due to transport downstream, assimilation by aquatic organisms, or adsorption by stream sediments.

Based on his review, Megahan concluded that the effects of fertilizer application in forested areas could be significantly reduced by avoiding application techniques that could result in direct deposition into the waterbody and by maintaining a buffer area along the streambank. Other researchers have presented information supporting Megahan's conclusions (Hetherington, 1985; Malueg et al., 1972).

Cost of Forest Chemical Applications

The cost of chemical management depends on the method of application (Table 3-41). Generally, chemicals are applied by hand, from an airplane or helicopter (aerial spray), or mechanically. When forest chemicals are applied mechanically, it is most common to use a boom sprayer.

Table 3-41. Average Costs for Chemical Management (Hansit, 2000; Holburg, 2000)

| Application Practice | Average Cost |
|----------------------|----------------|
| Hand Application | \$100/acre |
| Aerial Application | \$55-\$70/acre |

Best Management Practices

- ☐ For aerial spray applications, maintain and mark a buffer area of at least 50 feet around all watercourses and waterbodies to avoid drift or accidental application of chemicals directly to surface water (Figure 3-56).

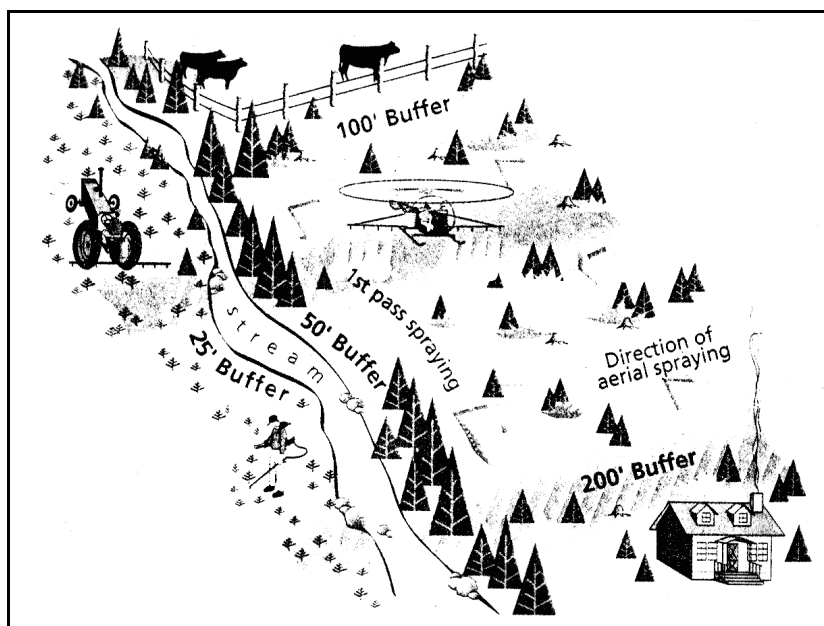


Figure 3-56. Observe minimum buffer zone widths during aerial applications of forest chemicals to protect water quality, people, and animals (Washington State DNR, 1997).

A wider buffer might be needed for major streams and lakes and for application of pesticides with high toxicity to aquatic life. A minimum 100-foot buffer is used for aerial applications and a 25-foot buffer for ground spray. Careful and precise marking of application areas for aerial applications helps avoid accidental contamination of open waters. For specific applications such as hypo hatchet or wick applicator, buffer area widths used for spray applications may be reduced.

- ☐ Apply pesticides and fertilizers during favorable atmospheric conditions.

Do not apply pesticides when wind conditions increase the likelihood of significant drift. It is also best to avoid pesticide application when temperatures are high or relative humidity is low because these conditions influence the rate of evaporation and enhance losses of volatile pesticides.

- ☐ *Ensure that pesticide users abide by the current pesticide label, which might specify whether users be trained and certified in the proper use of the pesticide; allowable use rates; safe handling, storage, and disposal requirements; and whether the pesticide may be used only under the provisions of an approved State Pesticide Management Plan.*

Consistency between management measures and practices for pesticides and those in the approved State Pesticide Management Plan helps ensure consistency in the method and means of use.

- ☐ *Locate mixing and loading areas, and clean all mixing and loading equipment thoroughly after each use, where pesticide residues will not enter streams or other waterbodies.*
- ☐ *Dispose of pesticide wastes and containers according to state and federal laws.*
- ☐ *Take precautions to prevent leaks and spills.*
- ☐ *Develop a spill contingency plan that provides for immediate spill containment and cleanup, and notification of proper authorities.*

Maintain an adequate spill and cleaning kit that includes the following:

- Detergent or soap.
 - Hand cleaner and water.
 - Activated charcoal, adsorptive clay, vermiculite, kitty litter, sawdust, or other adsorptive materials.
 - Lime or bleach to neutralize pesticides in emergency situations.
 - Tools such as a shovel, broom, and dustpan and containers for disposal.
 - Proper protective clothing.
- ☐ *Apply slow-release fertilizers when possible.*

This practice reduces potential nutrient leaching to ground water, and it increases the availability of nutrients for plant uptake.

- ☐ *Apply fertilizers during maximum plant uptake periods to minimize leaching.*
- ☐ *Base fertilizer type and application rate on soil and/or foliar analysis.*

Conduct foliar analysis approximately once per year to diagnose nutrient toxicities or deficiencies and to determine the correct fertilization program to follow. Foliar analysis is the process whereby leaves from trees are dried, ground, and chemically analyzed for their nutrient content. Compare the results of foliar analysis to available nitrogen,

phosphorus, potassium, and sulphur in the soils to be treated and to the requirements of the species.

- ☐ *Consider the use of pesticides as only one part of an overall program to control pest problems.*

Integrated Pest Management (IPM) strategies have been developed to control forest pests without total reliance on chemical pesticides. The IPM approach uses all available techniques, including chemical and nonchemical. An extensive knowledge of both the pest and the ecology of the affected environment is necessary for IPM to be effective.

- ☐ *Base selection of pesticide on site factors and pesticide characteristics.*

These factors include vegetation height, target pest, adsorption (attachment) to soil organic matter, persistence or half-life, toxicity, and type of formulation.

- ☐ *Check all application equipment carefully, particularly for leaking hoses and connections and plugged or worn nozzles. Calibrate spray equipment periodically to achieve uniform pesticide distribution and rate.*
- ☐ *Always use pesticides in accordance with label instructions, and adhere to all federal and state policies and regulations governing pesticide use.*

3J: Wetlands Forest Management

Management Measure for Wetlands Forest Management

Plan, operate, and manage normal, ongoing forestry activities (including harvesting, road design and construction, site preparation and regeneration, and chemical management) to adequately protect the aquatic functions of forested wetlands.

Management Measure Description

Forested wetlands provide many beneficial functions that need to be protected. Among these are floodflow alteration, sediment trapping, nutrient retention and removal, provision of important habitat for fish and wildlife, and provision of timber products. The extent of wetlands (including forested wetlands) in the continental United States has declined greatly in the past 40 years because of conversion to other land uses. There are currently approximately 100 million acres of wetlands in the 48 contiguous states, or about one-half of their extent at the time of European settlement. Although the rate of wetlands loss has slowed in recent years, the United States continues to sustain a net loss of approximately 100,000 acres per year. Given the historic and ongoing losses, it is critical that additional effects to wetlands be avoided and minimized to the maximum extent possible.

Potential effects of forestry operations in wetlands include the following:

- Loss and/or degradation due to discharges of dredged or fill material.
- Sediment production from road construction and use and equipment operation resulting in wetlands filling.
- Drainage alteration as a result of improper road construction. An excellent discussion of the relationship between forest roads and drainage is contained in the U.S. Forest Service document *Water/Road Interaction Technology Series* (USDA-FS, 1998b).
 - Stream obstruction caused by failure to remove logging debris.
 - Soil compaction caused by operation of logging vehicles during flooding periods or wet weather. Skid trails, haul roads, and log landings are areas where compaction is most severe (Figure 3-57).
 - Contamination from improper application or use of pesticides.
 - Loss of integrity of whole wetland landscapes (and the functions they serve) as a cumulative effect of incremental losses of small wetland tracts.

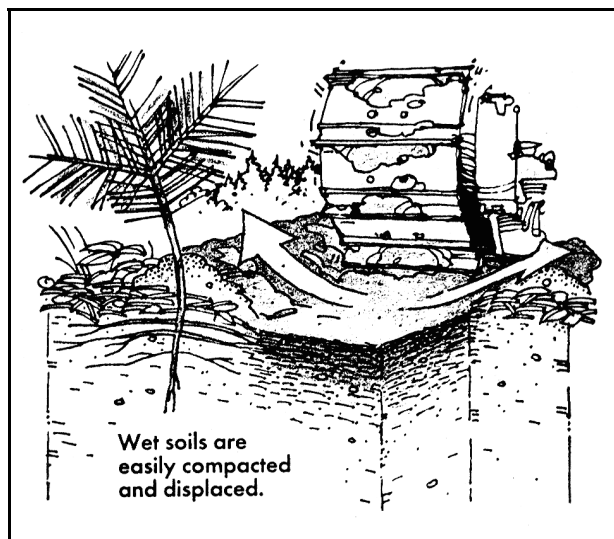


Figure 3-57. Heavy machinery operated on wet soils changes soil structure (Montana State University, 1991).

Potential adverse effects associated with road construction in forested wetlands are alteration of drainage and flow patterns, increased erosion and

sedimentation, habitat loss and degradation, and damage to existing timber stands. In an effort to prevent these potential adverse effects, section 404 of the Clean Water Act requires the use of appropriate BMPs for road construction and maintenance in wetlands so that flow and circulation patterns and chemical and biological characteristics are not impaired (see text below).

Harvest planning and selection of the right harvest system are essential in achieving the management objectives of timber production, ensuring stand establishment, and avoiding adverse effects on water quality and wetland habitat. The potential effects of reproduction methods and cutting practices on wetlands include changes in water quality, temperature, nutrient cycling, and aquatic habitat. Streams can also become blocked with logging debris if SMAs are not properly maintained or if appropriate practices are not employed in SMAs.

Site preparation includes but is not limited to the use of prescribed fire, chemicals, or mechanical site preparation. Extensive site preparation on bottoms where frequent flooding occurs can cause excessive erosion and stream siltation. The degree of acceptable site preparation is governed by the amount and frequency of flooding, soil type, and species suitability and is dependent on the regeneration method used.

Forestry in Wetlands: Section 404

Section 404 establishes a program that regulates the discharge of dredged or fill material into waters of the United States, including wetlands. The Corps and EPA jointly administer the program. The Corps administers the day-to-day program, including permit decisions and jurisdictional determinations; develops policy and guidance; and enforces Section 404 provisions. EPA develops and interprets environmental criteria used in evaluating permit applications; determines the scope of geographic jurisdiction; and approves and oversees state assumption. EPA also identifies activities that are exempt, enforces Section 404 provisions, and has the authority to elevate and/or veto Corps permit decisions. In addition, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and state resource agencies have important advisory roles.

Section 404(f) exempts normal silvicultural activities that are part of an established, ongoing forestry operation, including such practices as placement of bedding, seeding, cultivation, harvesting, and minor drainage. This exemption does not apply to activities that represent a new use of the wetland and that would result in a reduction in reach or impairment of flow or circulation of waters of the United States, including wetlands. In addition, Section 404(f) provides an exemption of discharges of dredged or fill material for the purpose of constructing or maintaining forest roads, where such roads are constructed or maintained in accordance with BMPs to assure that the flow and circulation patterns and chemical and biological characteristics of the navigable waters are not impaired, that the reach of the navigable waters is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized. Following are the section 404(f) regulations pertaining to forestry activities, including the BMPs for forest road construction or maintenance.

Code of Federal Regulations, Title 40, section 232.3:

Activities not requiring a section 404 permit

Except as specified in paragraphs (a) and (b) of this section, any discharge of dredged or fill material that may result from any of the activities described in paragraph (c) of this section is not prohibited by or otherwise subject to regulation under this part.

(a) If any discharge of dredged or fill material resulting from the activities listed in paragraph (c) of this section contains any toxic pollutant listed under section 307 of the Act, such discharge shall be subject to any applicable toxic effluent standard or prohibition, and shall require a section 404 permit.

(b) Any discharge of dredged or fill material into waters of the United States incidental to any of the activities identified in paragraph (c) of this section must have a permit if it is part of an activity whose purpose is to convert an area of the waters of the United States into a use to which it was not previously subject, where the flow or circulation of waters of the United States may be impaired or the reach of such waters reduced. Where the proposed discharge will result in significant discernable alterations to flow or circulation, the presumption is that flow or circulation may be impaired by such alteration.

Note: For example, a permit will be required for the conversion of a cypress swamp to some other use or the conversion of a wetland from silvicultural to agricultural use when there is a discharge of dredged or fill material into waters of the United States in conjunction with construction of dikes, drainage ditches or other works or structures used to effect such conversion. A conversion of section 404 wetland to a non-wetland is a change in use of an area of waters of the U.S. A discharge which elevates the bottom of waters of the United States without converting it to dry land does not thereby reduce the reach of, but may alter the flow or circulation of, waters of the United States.

(c) The following activities are exempt from section 404 permit requirements, except as specified in paragraphs (a) and (b) of this section:

...

(6) Construction or maintenance of farm roads, forest roads, or temporary roads for moving mining equipment, where such roads are constructed and maintained in accordance with best management practices (BMPs) to assure that flow and circulation patterns and chemical and biological characteristics of waters of the United States are not impaired, that the reach of the waters of the United States is not reduced, and that any adverse effect on the aquatic environment will be otherwise minimized. The BMPs which must be applied to satisfy this provision include the following baseline provisions:

(i) Permanent roads (for farming or forestry activities), temporary access roads (for mining, forestry, or farm purposes) and skid trails (for logging) in waters of the United States shall be held to the minimum feasible number, width, and total length consistent with the purpose of specific farming, silvicultural or mining operations, and local topographic and climatic conditions;

(ii) All roads, temporary or permanent, shall be located sufficiently far from streams or other water bodies (except for portions of such roads which must cross water bodies) to minimize discharges of dredged or fill material into waters of the United States;

(iii) The road fill shall be bridged, culverted, or otherwise designed to prevent the restriction of expected flood flows;

(iv) The fill shall be properly stabilized and maintained to prevent erosion during and following construction;

(v) Discharges of dredged or fill material into waters of the United States to construct a road fill shall be made in a manner that minimizes the encroachment of

trucks, tractors, bulldozers, or other heavy equipment within the waters of the United States (including adjacent wetlands) that lie outside the lateral boundaries of the fill itself;

(vi) In designing, constructing, and maintaining roads, vegetative disturbance in the waters of the United States shall be kept to a minimum;

(vii) The design, construction and maintenance of the road crossing shall not disrupt the migration or other movement of those species of aquatic life inhabiting the water body;

(viii) Borrow material shall be taken from upland sources whenever feasible;

(ix) The discharge shall not take, or jeopardize the continued existence of, a threatened or endangered species as defined under the Endangered Species Act, or adversely modify or destroy the critical habitat of such species;

(x) Discharges into breeding and nesting areas for migratory waterfowl, spawning areas, and wetlands shall be avoided if practical alternatives exist;

(xi) The discharge shall not be located in the proximity of a public water supply intake;

(xii) The discharge shall not occur in areas of concentrated shellfish production;

(xiii) The discharge shall not occur in a component of the National Wild and Scenic River System;

(xiv) The discharge of material shall consist of suitable material free from toxic pollutants in toxic amounts; and

(xv) All temporary fills shall be removed in their entirety and the area restored to its original elevation.

Best Management Practices

Wetland Harvesting Practices

- ☐ *Conduct forest harvesting according to preharvest planning designs and locations.*

Planning and close supervision of harvesting operations are needed to protect site integrity and enhance regeneration. Harvesting without regard to season, soil type, or type of equipment can damage the site productivity; retard regeneration; cause excessive rutting, churning, and puddling of saturated soils; and increase erosion and siltation of streams.

- ☐ *Establish a streamside management area adjacent to natural perennial streams, lakes, ponds, and other standing water in the forested wetland following the components of the SMA management measure.*
- ☐ *Ensure that planned harvest activities or chemical use does not contribute to problems of cumulative effects in watersheds of concern.*
- ☐ *Select the harvesting method to minimize soil disturbance and hydrologic effects on the wetland.*

In seasonally flooded wetlands, a guideline is to use conventional skidder logging that employs equipment with low-ground-pressure tires, cable logging, or aerial logging. Comparisons of cable logging and helicopter logging have concluded that helicopter operations cause less site disturbance, are more economical, and provide greater yield. Table 3-42 presents one set of harvesting system recommendations by type of forested wetland (Florida Division of Forestry, 1988). Another alternative is to conduct harvesting during winter months when the ground is frozen (see below).

Table 3-42. Recommended Harvesting Systems by Forested Wetland Site^a (Florida Department of Agriculture and Consumer Services, 1988).

| Site Type | Conventional | Conventional with Controlled Access ^b | Cable or Aerial | Barge or High Flotation Boom |
|-------------------------|----------------|--|-----------------|------------------------------|
| Flowing Water | | | | |
| <i>Mineral Soil</i> | | | | |
| Alluvial River Bottom | B | A | C | C |
| <i>Organic Soil</i> | | | | |
| Black River Bottom | B | A | C | C |
| Branch Bottom | A ^c | B | C | C |
| Cypress Strand | B | A | A | A |
| Muck Swamp | C | A | A | A |
| Nonflowing Water | | | | |
| <i>Mineral Soil</i> | | | | |
| Wet Hammock | B | A | C | C |
| <i>Organic Soil</i> | | | | |
| Cypress Dome | B | A | A | A |
| Peat Swamp | C | A | A | A |

A = recommended; B = recommended when dry; C = not recommended.

^a Recommendations include cost considerations

^b Preplanned and designated skid trails and access roads.

^c Log from the hill (high ground).

- ☐ *Use ultrawide, high-flotation tires on logging trucks and skidders to reduce soil compaction and erosion.*

Using dual-tired skidders and high-flotation tires for log hauling reduces soil damage, soil compaction, surface runoff, and sedimentation (Aust et al., 1994).

- ☐ *When ground skidding, use low-ground-pressure tires or tracked machines and confine skidding to a few primary skid trails to minimize site disturbance, soil compaction, and rutting. Adjust tire pressure on skidders during wet weather or when conducting forested wetland harvesting (Aust, Virginia Polytechnic Institute and State University, personal communication, 1999).*

Research conducted by Randy Foltz of the Intermountain Research Station in the Lowell Ranger District of the Willamette National Forest, Oregon (1994), addressed the use of variable tire pressure as a BMP for forest roads. His study showed that by reducing the tire pressure on logging trucks from their highway inflation of 90 psi to between 30 and

70 psi, sediment runoff was reduced on average by 67 percent. The percentage reduction in sediment runoff was directly correlated with the rainfall quantity and traffic volume.

- *When soils become saturated, suspend ground skidding harvesting operations. Use of ground skidding equipment during excessively wet periods can result in unnecessary site disturbance and equipment damage.*

Wetland Road Design and Construction Practices

- *Locate and construct forest roads according to preharvest planning.*

Forestry activities in wetlands are often subject to municipal, county, state, and federal regulations. Therefore, sufficient time should be set aside to obtain all necessary permits.

Improperly constructed and located forest roads can cause changes in hydrology, accelerate erosion, reduce or degrade fisheries habitat, and destroy or damage existing stands of timber.

- *Use temporary roads in forested wetlands.*

A temporary road in a wetland needs to provide adequate cross-road drainage at all natural drainageways. Temporary drainage structures include culverts, bridges, and porous material such as corduroy or chunkwood.

Construct permanent roads only to serve large and frequently used areas, as approaches to watercourse crossings, or to provide access for fire protection. Use the minimum design standard necessary for reasonable safety and the anticipated traffic volume. Various temporary wetland crossing options are compared in Table 3-43.

Blade the surface of a wetland to be as flat as possible prior to constructing a temporary road (Hislop and Moll, 1996, cited in Blinn et al., 1998). Do not disturb the root mat in any wetland that has grass mounds or other uneven vegetation. Any temporary wetland crossing is enhanced by using a root or slash mat to provide additional support to the equipment.

- *Construct fill roads only when absolutely necessary for access since fill roads have the potential to restrict natural flow patterns.*

Where construction of fill roads is necessary, use a permeable fill material (such as gravel or crushed rock) for at least the first layer of fill. The use of pervious materials helps maintain the natural flow regimes of subsurface water. Figure 3-58 demonstrates the different effects of impervious and pervious road fills on wetland hydrology. Permeable fill material is not a substitute for using bridges where needed or for installing adequately spaced culverts at all natural drainageways. Use this practice in conjunction with cross drainage structures to ensure that natural wetland flows are maintained (i.e., so that fill does not become clogged by sediment and obstruct flows).

Table 3-43. Temporary Wetland Crossing Options (Blinn, 1996).

| Crossing Option | Description | Application | Cost |
|-----------------------------------|--|---|--|
| Wood Mats | Individual cants that are strung together using two 3/16-inch galvanized steel cables to make a single-layer crossing. | Wet mineral or sandy soils or existing road beds. Wood mats are not recommended for undisturbed peat or very weak clay soils. They require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. | Approximately \$170 to initially construct a 10' x 12' mat |
| Wood Planks/Panels | Wood planks or panels are constructed using lumber planking to create a two-layer crossing. Parallel runners are laid down on each side where the vehicle's tires will pass and then lumber is nailed perpendicular to these runners. | Most wetland soils, if sized properly. The surface width needed depends on the soil strength. Wood plank crossings require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. | Approximately \$150 to initially construct an 8' x 12' wood plank |
| Wood Pallets | Wood-pallet crossing mats are sturdy, commercially available, multilayered variation of a three-layer wood pallet (used for shipping or storage) that has been designed specifically for traffic. | Most wetland soils, if sized appropriately. They require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. Most appropriate for hauling or forwarding operations. | Approximately \$350 for a commercial 8' x 16' pallet |
| Bridge Decking | The decking of a timber bridge can be used to cross a small wetland area. | Most wetland soils, if sized properly. Easy to install and remove. Require a relatively level ground surface. | Approximately \$6,000 for a 30' x 12' bridge |
| Expanded Metal Grating | Metal grating is relatively light and the surface is rough enough to provide some traction. Built by hand-placing the grating sections in the wheel paths. | Most shallow wetland soils, sandy soils, or on an existing road. It is not recommended for undisturbed peat or very weak clay soils. Performance is enhanced where there is an adequate root or slash mat to provide additional support. | Approximately \$100 for a 4' x 8' grate |
| PVC or HDPE Pipe and Plastic Road | A PVC and HDPE pipe mat is constructed using 4-inch diameter PVC or HDPE pipes that are tightly connected using galvanized steel cables. Plastic roads are similar to pipe mats except that they are not built to ease the transition of tires between the firm soil and the road. | Most wetland soils, if sized properly. Mat width needed depends on soil strength. Require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. | Approximately \$200 for a 4' x 12' pipe mat. Plastic road that is 8' x 40' costs approximately \$2,000 |

Table 3-43. (cont.)

| Crossing Option | Description | Application | Cost |
|--|--|--|---|
| Tire Mats | A tire mat or panel of tires created by interconnecting tire sidewalls with corrosion-resistant fasteners. Tire threads are also used in some designs. Mats of varying length and width can be created. | Most wet mineral soils with different designs for distinct soils and situations. Tire mats require a relatively level surface with grades up to 5 percent, a fairly straight alignment, and no cross slope. | Approximately \$300 for a 5' x 10' mat |
| Corduroy | Corduroy is a crossing made of brush, small logs cut from low-value and noncommercial trees on-site, or mill slabs that are laid perpendicular or parallel to the direction of travel. | Most wetland soils. Corduroy crossings require a relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. | Low |
| Pole Rails | When attempting to support skidding or forwarding machinery equipped with high flotation or dual tires, one or more straight hardwood poles cut from on-site trees can be laid parallel to the direction of travel below each wheel. | Skidding and felling machinery equipped with wide, high-flotation tires and used across small mineral soil wetlands. Should only be used on relatively level surface with grades up to 4 percent, a fairly straight alignment, and no cross slope. | Low |
| Wood Aggregate | Wood particles ranging in size from chips to chunks can provide cohesion and support on soft soils. Wood aggregate is used in the same way as gravel, except that it is lighter and temporary due to natural deterioration. | The traffic capability of most wet soils can be improved substantially with the application of wood aggregate. Can be used on a variety of grades, alignments, and cross slopes. | Competitive with local sources of gravel fill. |
| Equipment with Wide Tires, Duals, Bodies, or Tire Tracks | These mobility options provide a method for increasing the contact area between the equipment and the soil so that the machine's weight is spread over a larger surface area. | Many wetland soils. Performance is enhanced in areas where there is adequate root or slash mat to provide additional support to the equipment. | Wide tires may cost more than \$4,000 each, tire tracks may cost approximately \$7,000 for a set of two tracks. |
| Central Tire Inflation (CTI) | CTI is a low-ground-pressure option currently for use on hauling vehicles only, but will likely be available on other equipment in the future. | Many wetland soils. The reduced tire pressure, when used with radial ply tires, results in a larger tire "footprint," which reduces the vehicle pressure applied to the ground. | Cost depends on the number of axles retrofitted. 18 axles = \$16,000 |

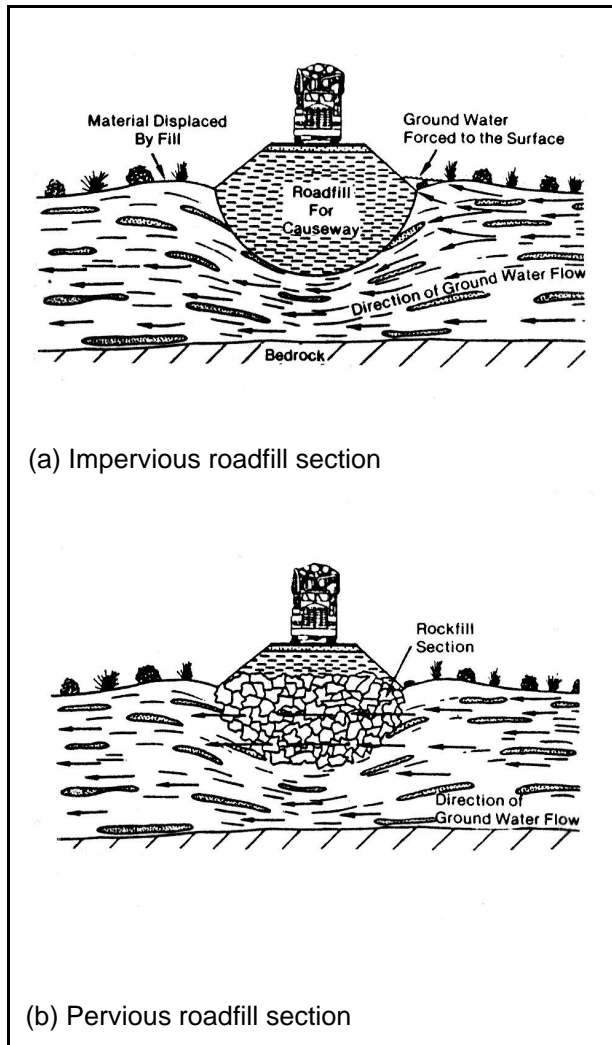


Figure 3-58. Comparison of impervious (a) and pervious (b) roadfill sections. Impervious roadfill consolidates natural material and restricts groundwater flow. Pervious roadfill allows movement of groundwater through it and minimizes flow changes (adapted from Thronson, 1979).

- ☐ *Provide adequate cross drainage to maintain the natural surface and subsurface flow of the wetland.*

This can be accomplished through adequate sizing and spacing of water crossing structures, proper choice of the type of crossing structure, and installation of drainage structures at a depth adequate to pass subsurface flow. Designed and constructed according to these considerations helps ensure that bridges, culverts, and other structures do not perceptibly diminish or increase the duration, direction, or magnitude of the minimum, peak, or mean flow of water on either side of the structure.

- ☐ *Construct roads at natural ground level to minimize the potential to restrict flowing water.*

Float the access road fill on the natural root mat. If the consequences of the natural root mats' failing are serious, use reinforcement materials such as geotextile fabric, geo-grid mats, or log corduroy. Figure 3-59 depicts a cross section of the practice of floating the road. Protect the root mat beneath the roadway from equipment damage by diverting through traffic to the edge of the right-of-way, shear-blading stumps instead of grubbing, and using special wide-pad equipment. Also, protect the root mat from damage or puncture by using fill material that does not contain large rocks or boulders.

- ☐ *Discharges of dredged or fill material into wetlands or other waters of the United States must comply with CWA section 404 (see text above).*

Practices for Crossing Wetlands in Winter

Winter provides an opportunity to cross wetlands with little effect. Roads are often constructed across wetlands in winter to take advantage of frozen ground.

- ☐ *The following are recommendations for crossing wetlands in winter, for all wetland types (Minnesota Division of Forestry, 1995):*
 - If permanent structures are to be used, follow BMP installation guidelines for permanent roads.
 - Select the shortest practical route to minimize potential problems with drifting snow and crossing of open water.

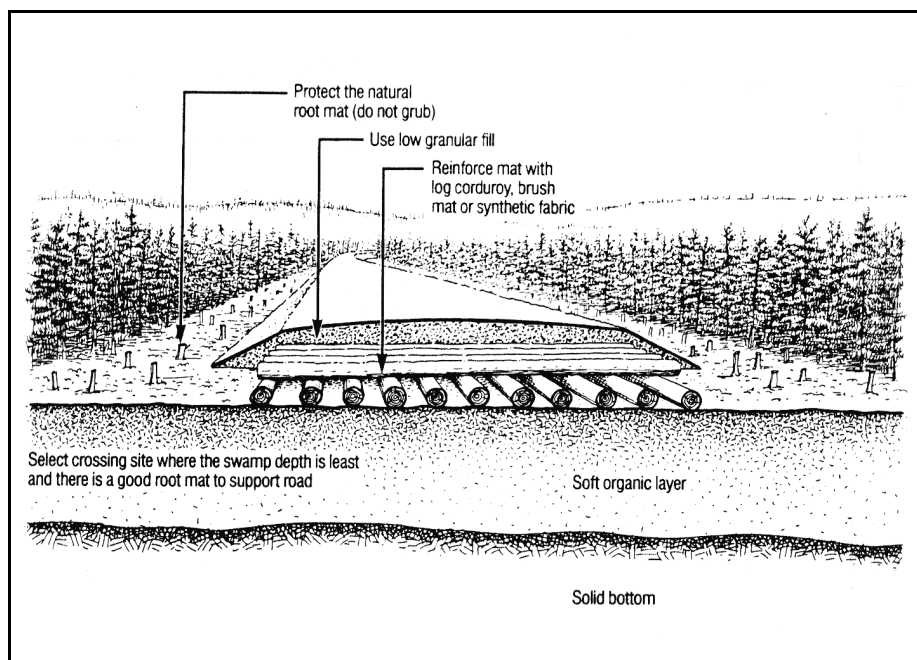


Figure 3-59. Elements of a road crossing through a swamp wetland, cross section (Ontario MNR, 1990).

- Avoid crossing open water or active springs. If crossing is unavoidable, temporary crossings are preferred over permanent crossings. These can be ice bridges, temporarily installed bridges, or timber mats.
- Avoid using soil fill.
- Install structures that block water flow so that they can be easily removed prior to the spring thaw. Removed these structures during a winter thaw.

- Use planking, timber mats, or other support alternatives to improve the capability of the road to support heavy traffic. If removal would cause more damage than leaving them in place, these structures can be left as permanent sections on frozen roads.
- Avoid clearing practices that result in berms of soil or organic material, which can disrupt normal water flow in wetlands.
- Do not operate machinery during a winter thaw. Resume operations only when conditions are adequate to support equipment.
- Remove temporary fills and structures to the extent practical when no longer needed.
- Install buffer strips near open water.
- Anchor temporary structures at one end only to allow them to move aside during high-water flows.

- ☐ *To avoid excessive damage, equipment operations are best avoided on any portion of a road where ruts are deeper than 6 inches below the water surface for a continuous distance of more than 100 yards (Wiest, 1998).*

Wetland Site Preparation and Regeneration Practices

- ☐ *Select a regeneration method that meets the site characteristics and management objectives.*

Choice of regeneration method has a major influence on the stand composition and structure and on the silvicultural practices to be applied over the life of the stand. Natural regeneration may be achieved by clearcutting the existing stand and relying on regeneration from seed from adjacent stands, the cut trees, or stumps and from root sprouts (coppice). Successful regeneration depends on recognizing the site type and its characteristics, evaluating the stocking and species composition in relation to stand age

and site capability, planning regeneration options, and using sound harvesting methods. Schedule harvest during the dormant season to take advantage of seed sources and to favor coppice regeneration. Harvest trees at a stump height of 12 inches or less when practical to encourage vigorous coppice regeneration. Artificial regeneration may be accomplished by planting of seedlings or direct seeding. Table 3-44 presents an example of regeneration system recommendations (Georgia Forestry Association, 1990).

Table 3-44. Recommended Regeneration Systems by Forested Wetland Type (Georgia Forestry Association, 1990)

| Type | Natural Regeneration | | | | Artificial Regeneration | | |
|------------------------------------|----------------------|-----------------|--------------|------------------------|-------------------------|-------|-------------|
| | Clearcut | Group Selection | Shelter Wood | Seed ^a Tree | Mechanical Site Prep. | Plant | Direct Seed |
| Flood Plains, Terraces, Bottomland | | | | | | | |
| Black River | A | B | B | C | D | C | C |
| Red River | A | B | B | C | D | B | B |
| Branch Bottoms | A | B | B | C | D | C | C |
| Piedmont Bottoms | A | B | B | C | D | B | B |
| Muck Swamps | A | C | C | C | D | C | C |
| Wet Flats | | | | | | | |
| Pine Hammocks & Savannahs | A | B | B | B | A | A | B |
| Pocosins or Bays | A | C | B | B | B | B | B |
| Cypress Strands | A | C | C | C | D | C | C |
| Cypress Domes: Peat Swamps | | | | | | | |
| Peat Swamps | A | C | C | C | C | C | C |
| Cypress Domes | A | C | C | C | D | C | C |
| Gulfs, Coves, Lower Slopes | A | B | B | C | C | B | C |

A = highly effective; B = effective; C = less effective; D = not recommended.

^a Seed tree cuts are not recommended on first terraces of flood plains, terraces, and bottomland.

- ☐ *Conduct mechanized site preparation and planting of sloping areas on the contour.*
- ☐ *To reduce disturbance, conduct bedding operations in high-water-table areas during dry periods of the year.*

The degree of acceptable site preparation depends on the amount and frequency of flooding, the soil type, and the species suitability.

- ☐ *Minimize soil degradation by limiting operations on saturated soils.*

Wetland Fire Management Practices

Site preparation burns in wetlands are often the most severe (hottest) and have the most potential to increase surface runoff and soil erosion.

- ☐ *Conduct burns in a manner such that they do not completely remove the organic layer from the forest floor.*
- ☐ *Do not construct firelines that will drain wetlands.*

Chemical Management Practices

- ☐ *Apply herbicides by injection to individual stems.*
- ☐ *For chemical and aerial fertilizer applications, maintain and mark a buffer area around all surface water to avoid drift or accidental direct application.*

Avoid application of pesticides with high toxicity to aquatic life, especially aerial applications. Aerial applications need a minimum buffer of 50 feet from water (25 feet for fertilizers), 100 feet from agricultural lands, and 200 feet from homes. Motorized ground applications need a minimum buffer of 25 feet from water. The first pass of each application is to be made parallel to the buffer zone. A buffer is not necessary for hand applications; however, hand-applied forest chemicals have to be applied to specific targets, and chemicals need to be prevented from entering the water. Before any application of a chemical, consult state laws and regulations for chemical application. Have a person licensed in chemical application perform all work (Washington State DNR, 1997).

- ☐ *Apply slow-release fertilizers when possible.*

This practice reduces the potential of the nutrients leaching to ground water, and it increases the availability of nutrients for plant uptake.

- ☐ *Apply fertilizers during maximum plant uptake periods to minimize leaching.*
- ☐ *Base fertilizer type and application rate on soil and/or foliar analysis.*

To determine fertilizer formulations, it is best to compare available nitrogen, phosphorus, potassium, and sulphur in the soils to be treated with the requirements of the species to be sown.

EPA and Corps of Engineers Memorandum to the Field

Mechanical Site Preparation Activities and CWA Section 404

Under certain circumstances, a CWA section 404 permit is required for mechanical silvicultural site preparation activities in wetlands. In 1995, EPA and the U.S. Army Corps of Engineers issued a memorandum to clarify the applicability of section 404 to mechanical silvicultural site preparation activities in the Southeast.

The memorandum (particularly the descriptions of wetlands, activities, and BMPs in the memorandum) focuses on the southeastern United States. However, the guidance in the memorandum is generally applicable when addressing mechanical silvicultural site preparation activities in wetlands elsewhere in the country.

The memorandum clarifies the applicability of forested wetlands BMPs to silvicultural site preparation activities for the establishment of pine plantations in the Southeast. Mechanical silvicultural site preparation activities conducted in accordance with the BMPs discussed below, which are designed to minimize effects to the aquatic ecosystem, will not require a Clean Water Act section 404 permit. These BMPs further recognize that certain wetlands should not be subject to unpermitted mechanical silvicultural site preparation activities because of the adverse nature of potential effects associated with these activities on these sites.

EPA and the Corps will continue to work closely with state forestry agencies to promote the implementation of consistent and effective BMPs that facilitate sound silvicultural practices. In those states where no BMPs specific to mechanical silvicultural site preparation activities in forested wetlands are currently in place, EPA and the Corps will coordinate with those states to develop BMPs. In the interim, mechanical silvicultural site preparation activities conducted in accordance with the memorandum will not require a section 404 permit.

Circumstances in Which Mechanical Site Preparation Activities Require a Section 404 Permit

Mechanical silvicultural site preparation activities can have measurable and significant effects on aquatic ecosystems when conducted in wetlands that are permanently flooded, intermittently exposed, or semipermanently flooded, and in certain additional wetland communities that exhibit aquatic functions and values that are more susceptible to effects from these activities. For the wetland types identified below, mechanical silvicultural site preparation activities require a permit so that individual proposals can be evaluated on a case-by-case basis for site preparation and potential associated environmental effects.

A permit will be required in the following areas unless they have been so altered through past practices (including the installation and continuous maintenance of water management structures) as to no longer exhibit the distinguishing characteristics described below (see Circumstances in which Mechanical Silvicultural Site Preparation Activities Do Not Require a Permit below). Of course, discharges incidental to activities in any wetlands that convert waters of the United States to non-waters always require authorization under Clean Water Act section 404.

Permanently flooded wetlands, intermittently exposed wetlands, and semipermanently flooded wetlands. Permanently flooded wetland systems are characterized by water that covers the land surface throughout the year in all years. Intermittently exposed wetlands are characterized by surface water that is present throughout the year except in years of extreme drought. Semipermanently flooded wetlands are characterized by surface water that persists throughout the growing season in most years and, even when surface water is absent, a water table usually at or very near the land surface. Examples of these wetlands include cypress-gum swamps, muck and peat swamps, and cypress strands/domes.

Riverine bottomland hardwood wetlands. These are seasonally flooded (or wetter) bottomland hardwood wetlands within the first or second bottoms of the floodplains of river systems. Site-specific characteristics of hydrology, soils, and vegetation and the presence of the alluvial features mentioned in the memorandum determine the boundary

of riverine bottomland hardwood wetlands. National Wetlands Inventory maps provide a useful reference for the general location of these wetlands on the landscape.

White cedar swamps. These wetlands are greater than 1 acre in headwaters and greater than 5 acres elsewhere. They are underlain by peat of greater than 1 meter and vegetated by natural white cedar representing more than 50 percent of the basal area, where the total basal area for all tree species is 60 square feet or greater.

Carolina bay wetlands. These are oriented, elliptical depressions with a sand rim that are either underlain by clay-based soils and vegetated by cypress or underlain by peat of greater than 0.5 meter and typically vegetated with an overstory of red, sweet, and loblolly bays.

Nonriverine forest wetlands. The wetlands in this group are rare, high-quality wet forests, with mature vegetation, located on the Southeastern Coastal Plain. Their hydrology is dominated by high water tables. Two forest community types fall into this group: (1) nonriverine wet hardwood forests, poorly drained mineral soil interstream flats (comprising 10 or more contiguous acres), typically on the margins of large peatland areas, seasonally flooded or saturated by high water tables, with vegetation dominated (greater than 50 percent of basal area per acre) by swamp chestnut oak, cherrybark oak, or laurel oak alone or in combination, and (2) nonriverine swamp forests, very poorly drained flats (comprising 5 or more contiguous acres), with organic soils or mineral soils with high organic content, seasonally to frequently flooded or saturated by high water tables, with vegetation dominated by bald cypress, pond cypress, swamp tupelo, water tupelo, or Atlantic white cedar alone or in combination.

Low pocosin wetlands. These are the central, deepest parts of domed peatlands on poorly drained interstream flats, underlain by peat soils greater than 1 meter, typically vegetated by a dense layer of short shrubs.

Wet marl forests. These are hardwood forest wetlands underlain with poorly drained, marl-derived, high-pH soils.

Tidal freshwater marshes. These wetlands are regularly or irregularly flooded by fresh water. They have dense herbaceous vegetation and occur on the margins of estuaries or drowned rivers or creeks.

Maritime grasslands, shrub swamps, and swamp forests. These are barrier island wetlands in dune swales and flats, underlain by wet mucky or sandy soils. They are vegetated by wetland herbs, shrubs, and trees.

Circumstances in Which Mechanical Site Preparation Activities Do Not Require a Section 404 Permit

Mechanical silvicultural site preparation activities in wetlands that are seasonally flooded, intermittently flooded, temporarily flooded, or saturated or are in existing pine plantations and other silvicultural sites (except as listed above) do not require a permit if conducted according to the BMPs listed above in *Site Preparation When a Permit is Not Required*. Of course, silvicultural practices conducted in uplands never require a Clean Water Act section 404 permit (see *Code of Federal Regulations* text above).

Seasonally flooded wetlands are characterized by surface water that is present for extended periods, especially early in the growing season, but is absent by the end of the season in most years. (When surface water is absent, the water table is often near the surface.) Intermittently flooded wetland systems are characterized by substrate that is usually exposed and the presence of surface water for variable periods without detectable seasonable periodicity. Temporarily flooded wetlands are characterized by surface water that is present for brief periods during the growing season, but also by a water table that usually lies well below the soil surface for most of the season. Saturated wetlands are characterized by substrate that is saturated to the surface for extended periods during the growing season, but also by the absence of surface water most of the time. Examples typical of these wetlands include pine flatwoods, pond pine woodlands, and wet flats (e.g., certain pine/hardwood forests).

Best Management Practices

The BMPs below are from a joint EPA and Corps of Engineers *Memorandum to the Field* (see below) on the application of BMPs to mechanical silvicultural site preparation activities for the establishment of pine plantations in the Southeast. The guidance is, however, generally applicable to mechanical silvicultural site preparation activities in wetlands elsewhere in the country. Every state in the Southeast has developed BMPs for forestry to protect water quality, and all but two have also developed specific BMPs for forested wetlands.

The BMPs listed here are the minimum to be applied for mechanical silvicultural site preparation activities in forested wetlands where these activities do not require a permit (see *Memorandum to the Field* below). In circumstances where a permit is required, BMPs specifically required for the individual operation will be detailed in the permit.

The BMPs below were developed because silvicultural practices have the potential to result in effects on an aquatic ecosystem. Mechanical silvicultural site preparation activities have the potential to cause effects such as soil compaction, turbidity, erosion, and hydrologic modifications if the activities are not effectively controlled by BMPs.

- ☐ *Position shear blades or rakes at or near the soil surface and windrow, pile, and otherwise move logs and logging debris by methods that minimize dragging or pushing through the soil to minimize soil disturbance associated with shearing, raking, and moving trees, stumps, brush, and other unwanted vegetation.*
- ☐ *Conduct activities in such a manner as to avoid excessive soil compaction and maintain soil tilth.*
- ☐ *Arrange windrows in such a manner as to limit erosion, overland flow, and runoff.*
- ☐ *Prevent disposal or storage of logs or logging debris in SMAs.*
- ☐ *Maintain the natural contour of the site and ensure that activities do not immediately or gradually convert the wetland to a non-wetland.*
- ☐ *Conduct activities with appropriate water management mechanisms to minimize off-site water quality effects.*

The full text of the memorandum is available on the Internet at
<www.epa.gov/OWOW/wetlands/silv2.html>.

Using Management Measures to Prevent and Solve Nonpoint Source Pollution Problems in Watersheds

Management measures and associated management practices applied at harvest sites and along roads provide essential control of erosion and sedimentation, and it is important that all management measures and management practices applicable to a harvest site or road be applied to limit as much as possible the amount of soil erosion and the potential for water pollution that can result from forest harvesting activities.

The watershed perspective enables the practitioner to go beyond the effects from a single harvest area or individual road to consider all activities occurring within the watershed that could affect water resources. Each activity can have its own effect on water quality, and the watershed perspective views the effects due to harvesting and road construction within the context of the overall effects of forestry activities together with other activities such as recreational uses and conversions of land use. It is the collective effects of all of these activities that determine how water quality is affected, and these cumulative effects on water quality wouldn't normally be recognized if the effects arising from individual harvesting activities are considered alone.

Research has determined that the use of BMPs on forestland results in smaller increases in nutrients and suspended sediment load after logging than when BMPs are not used. This points to the need for a watershed approach to water quality management, and such an approach within the context of forest harvesting and road construction and use implies, at a minimum, the following:

- Applying management measures and management practices that are appropriate not only to the harvest site, but that take into consideration the current state of water quality in receiving waters, given all that is happening in the watershed, and the effect that forestry activities could have.
- The foreseeable future needs to be considered as well. Some effects of harvesting and road building can last beyond the duration of a harvest or the completion of road construction, and if other activities that could effect water quality are planned in the watershed in the timeframe during which those effects are expected to continue, mitigation of these long-term effects might be necessary.
- Maintenance of older roads built with outdated management practices (those dating from the 1950s to the mid-1970s), which can be significant sources of sediment, is an essential part of forested watershed management. Long-term management plans for forest roads include their inventory, maintenance, and closure; and closure of unused, unneeded, and high-erosion-risk roads.

The EPA Watershed Approach

Watersheds are areas of land that drain to a single stream or other water resource. Watersheds are defined solely by drainage areas and not by land ownership or political boundaries.

Since 1991, the USEPA has promoted the watershed protection approach as a holistic framework for addressing complex pollution problems such as those from nonpoint sources. The watershed protection approach is a comprehensive planning process that considers all natural resources in the watershed, as well as social, cultural, and economic factors. The process tailors workable solutions to ecosystem needs through participation and leadership of stakeholders.

Although watershed approaches may vary in terms of specific objectives, priorities, elements, timing, and resources, all should be based on the following guiding principles.

- *Partnerships.* People affected by management decisions are involved throughout and help shape key decisions. Cooperative partnerships among Federal, State, and local agencies and non-governmental organizations with interests in the watershed are formed. This approach ensures that environmental objectives are well integrated with those for economic stability and other social/cultural goals of the area. It also builds support for action among those individuals who are economically dependent upon the natural resources of the area.
- *Geographic focus.* Resource management activities are coordinated and directed within specific geographic areas, usually defined by watershed boundaries, areas overlaying or recharging ground water, or a combination of both.
- *Sound management techniques based on strong science and data.* Collectively, watershed stakeholders employ sound scientific data, tools, and techniques in an iterative decision-making process. Typically, this includes:
 - Assessment and characterization of the natural resources in the watershed and the people who depend upon them.
 - Goal setting and identification of environmental objectives based on the condition or vulnerability of resources and the needs of the aquatic ecosystem and the people.
 - Identification of priority problems.
 - Development of specific management options and action plans.
 - Implementation, evaluation, and revision of plans as needed.

Operating and coordinating programs on a watershed basis makes good sense for environmental, financial, social, and administrative reasons. For example, by jointly reviewing the results of assessment efforts for drinking water protection, pollution control, fish and wildlife habitat protection, and other resource protection programs, managers from all levels of government can better understand the cumulative effects of

various human activities and determine the most critical problems within each watershed. Using this information to set priorities for action allows public and private managers from all levels to allocate limited financial and human resources to address the most critical needs. Establishing environmental indicators helps guide activities toward solving those high-priority problems and measuring success.

The final result of the watershed planning process is a plan that is a clear description of resource problems. Goals to be attained, and identification of sources for technical, educational, and funding assistance needed. The successful plan provides a basis for seeking support and for maximizing the benefits of that support.

Cumulative Effects

The watershed approach is a useful mechanism for managing the resources within a defined geographical boundary, and it provides a basis for cumulative effects assessment as well. Though it is not a formal analytical framework for the evaluation of cumulative effects, the watershed approach shares with cumulative effects assessment (CEA) a consideration of all relevant activities and influences. Furthermore, a watershed is a natural geographic boundary for the analysis of cumulative effects on water quality because the influences of upstream activities can create a cumulative effect on downstream water quality.

Definition

Current environmental regulations provide at least two definitions of cumulative effects (CEs):

Cumulative effect is the effect on the environment which results from the incremental effect of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7).

Cumulative effects are the changes in an aquatic ecosystem that are attributable to the collective effect of a number of individual discharges of dredged or fill material. Although the effect of a particular discharge may constitute a minor change in itself, the cumulative effect of numerous such piecemeal changes can result in a major impairment of the water resources and interfere with the productivity and water quality of existing aquatic ecosystems (40 CFR 230.11).

CEs can be very difficult to quantify and assess, and they are best understood by focusing on the mechanisms by which watershed processes are affected (Reid, 1993). Watershed processes are affected when a land use activity causes a change in the production and transport of one or more watershed products (water, sediment, organic material, chemicals, or heat). Most land use activities affect only one of four aspects of the environment—vegetation, soils, topography, or chemicals—and other watershed changes result from initial effects on these. Understanding CEs within a watershed context involves: (1) understanding how specific land uses affect vegetation, soils,

topography, or chemicals; (2) determining to what extent these changes affect watershed processes; and (3) understanding how changes to vegetation, soils, topography, chemicals, and watershed processes affect particular resources and values.

Cumulative effects can be additive or synergistic (MacDonald, 2000). Additive effects are those in which each land use activity creates a discrete effect on an individual resource or value and the total effect is the sum of the individual effects. Synergistic effects are those in which the combined effect of individual activities on a resource or value are greater than the sum of their individual effects. Synergistic effects can occur through the interaction of different chemicals or types of effects on a single resource. Many times with synergistic effects, each effect is analyzed and determined to *individually* not be detrimental to a particular resource, but the combined or cumulative effect of the three activities do create a significant impact on a resource.

Assessment of CEs should also take into account whether they are on-site or off-site. On-site CEs can occur if a change persists long enough for later activities to affect the same resource or for the effects of off-site activities to be transported to the site of the change. The temporal dimension of on-site CEs is important to their assessment, while the spatial dimension is limited to the original site of the effect. Off-site CEs occur when a land use activity causes a change in a watershed process such that effects are created at a location other than where the original land use activity occurred. Off-site CEs occur when watershed processes are altered long enough for the off-site effects to accumulate over time; when watershed processes are affected at multiple sites in a watershed and the watershed products that are affected are transported to the same site, or when an off-site effect interacts with an on-site effect. Both the temporal and spatial dimension of off-site CEs are important to consider when analyzing them.

The Importance of Considering and Analyzing Cumulative Effects

Cumulative effects are of concern with respect to forest roads; forest road construction, use, and maintenance; and forest harvesting because the changes that can occur in watershed processes following these activities can persist for many years. This persistence increases the potential for cumulative effects to occur.

Traditionally, effect assessment has evaluated the likely effects of single actions on the environment. But single areas and ecosystems are often affected by more than single actions or projects. The collective effect of numerous small actions can cause serious degradation, though the effects of each small action by itself might be undetectable. Even after an area or ecosystem has been degraded, an analysis of the effects of an additional action might conclude that there would be only minor or no significant effect. An analysis of the additive effect of the single additional action—the cumulative effects—however, might conclude that the action could be detrimental (USEPA, 1992). Cumulative effects analysis also differs from many types of traditional environmental assessment in the need to predict the consequences of “reasonably foreseeable future actions.”

The importance of cumulative effects assessment, then, lies in the difference between traditional effect assessment and cumulative effects assessment. Traditional effect assessment is performed with respect to the proposed disturbance, whereas cumulative effects assessment is performed with respect to valued environmental functions (USEPA,

1992). An assessment of an action might have little to no detectable significant effect in terms of pollutant additions or habitat loss, as determined by traditional effect assessment, but might have a clearly disturbing effect on ecosystem functioning as determined by cumulative effects assessment. As more habitat is lost or fragmented and pollutants are generated, environmental stewardship demands that we pay more attention to the collective effects of our actions on ecosystems and their functioning and place less stress on the absolute quantities of pollutants that are generated or habitat lost as a result of each action. Cumulative effects assessment is the means to do this.

Problems in Cumulative Effects Analysis

Cumulative effects analysis, as conceived, is a powerful approach to assessing the overall effect of our actions on the environment and of managing those actions such that species and ecosystems continue to function properly. Unfortunately, many practical problems are associated with performing a cumulative effects analysis, including the following:

- Because total maximum daily load (TMDL) assessments calculate all point source and non-point source pollution for a watershed, a TMDL is essentially a cumulative effects analysis. Agencies responsible for implementing TMDL's have been hesitant to do so because of limitations in personnel, water quality data, and understanding of watershed dynamics. There is also a lack of available methodologies for tracking pollutants such as clean sediment (MacDonald, 2000).
- Ecosystems are complex and our knowledge of their workings is still limited, yet cumulative effects assessment involves identification of the ecosystem components of relevance that will be the focus of the cumulative effects analysis (Berg et al., 1996).
- The boundaries for cumulative effects assessment might be different from those relevant to other analyses, such as nonpoint source pollution or TMDL assessment. A single watershed might be appropriate for assessing nonpoint source pollution, but many watersheds might be involved in cumulative effects analysis for effects on forest conservation (Berg et al., 1996).
- Current guidelines published by the CEQ (1997) do not explicitly address natural processes, spatial variability, and temporal variability within project areas. Natural variability and rates of recovery can affect prediction and detection of cumulative impacts (MacDonald, 2000).
- Effects from individual projects often last for no longer than one human generation, whereas the time frame for changes in ecosystem processes that are the focus of cumulative effects assessment is typically an order of magnitude longer (Berg et al., 1996).
- The effects of most management activities diminish over time, and so then does the magnitude of possible cumulative effects. This leads to a problem of temporal scale related to determining the magnitude of human-induced cumulative effects relative to natural variability over a long time lag (MacDonald, 1997).

- The scale of cumulative effects analysis is very different from that used for traditional effect assessment, and effects due to individual projects might be undetectable using the analytical methods necessary for cumulative effects assessment. For instance, patterns on the landscape, such as whether 10,000 hectares are contiguous or not, are relevant for cumulative effects analysis; a small clearcut, important at the local scale, might not appear in an analysis at a scale of thousands of hectares (Berg et al., 1996).
- When working at the scale necessary for cumulative effects assessment, areas that contain fragmented jurisdictions with multiple-agency oversight, differences in regulatory structure between jurisdictions and agencies, and conflicting interests and mandates are involved (Berg et al., 1996).
- To adequately assess the future consequences of multiple perturbations in a watershed, the status of ecosystem recovery from past perturbations must be estimated. Complexity of the analysis increases because recovery times for various components in a system are not necessarily identical, and knowledge is often inadequate to quantify recovery rates. For instance, “recovery” of stream flow magnitude and rate after timber harvest is largely a function of the rate of revegetation of the watershed. Sediment produced by roads associated with the timber harvest will typically take much longer to move through stream channels and “recover” to pre-road levels. Understanding of both types of recovery is needed and they cannot be substituted for each other.

Within the context of forestry activities and forested watersheds, the following difficulties are encountered when attempting to assess cumulative effects (Reid, 1993):

- The effects of forest management activities on streamflow has been studied extensively, yet it remains difficult to determine what effects a management activity will have on a stream because hydrologic response varies greatly with basin size, flow magnitude, season, climate, geology, and type and intensity of forest management activity. The results of studies done in one basin are therefore difficult to extrapolate to other basins. It can be important to determine whether forestry activities will have effects on watershed processes because of the potential consequences if the effects are substantial enough, but such a determination can be costly. It can also be costly, however, to take measures to prevent watershed effects from forestry activities when such effects might not materialize.
- Variability in storm intensity and runoff processes limit the ability to detect human-induced effects on streamflow. Even with years of monitoring data, it can be difficult to distinguish between human-induced effects and natural variability in watershed processes. The process of determining cause and effect is complicated by the fact that different activities can cause similar responses and one activity might not always elicit the same response.
- The dynamics of natural forest communities must be understood to interpret or predict the effects of changes, and natural disturbance frequencies, patterns, characteristics, recovery rates; these are not well understood. Monitoring would be a useful tool to increase our understanding of these dynamics, but the sequences of changes that can lead to CEs, or the combinations of changes that

can lead to CEs are varied and can take long periods of time to take effect (e.g., 50 years). Monitoring these effects is often not possible due to the time frame involved.

- Paired watershed experiments, in which one watershed is treated, another similar watershed is left untreated, and the differences monitored, lack randomness in choosing watersheds to be studied, and therefore lack statistical validity and apply only to the watersheds studied.
- If a system responds incrementally, changes can be easily identified; but many changes, such as landslides or floods, do not occur incrementally. Instead, changes, such as loss of vegetation water storage and increased soil compaction, might be relatively benign and accumulate until some event, such as a 50-year storm, triggers a substantial response. These thresholds at which substantial and important CEs occur often cannot be predicted, and knowledge of them is based on studying them after they occur.
- The rate of recovery from land use depends on the type of land use and on the watershed processes that are affected.

Approaches to Cumulative Effects Analysis

Four general approaches for predicting cumulative effects include the use of analytical models, assessments of previous management activities, use of a collection of procedures that address specific anticipated impacts, and use of a checklist to indicate what cumulative effects might be expected to occur because of a land use activity. Models can be used to predict changes to physical or biological aspects of a watershed, or to predict the magnitude of change in a watershed process or characteristic that might trigger a particular type of impact (Reid, 1993). Models are useful because the cumulative effects of repeated timber harvests in a watershed could be estimated or monitored experimentally only in a study lasting several centuries (Ziemer and Lisle, 1991). While modeling does represent a simplification of nature and depends on a modeler's skill, modeling results can represent average conditions and explore the effects of large spatial and temporal scales. They can also be useful for conducting “what if” analyses, where the effects of different sequences of harvesting or precipitation events, for example, are explored. This characteristic of models contrasts sharply with monitoring studies, in which the unique sequence of events that occurs during a monitoring distorts the results.

Many models have been developed for specific locations and cannot easily be applied to other areas. The limitations of the models are stated in user's guides or instructions for use, but the models, nevertheless, are often put into general use regardless of whether the assumptions of the model are valid for a particular application or whether the methods of the model have been tested and validated (Reid, 1993). Many models are meant to be used to predict particular impacts, yet their methods are used to test for the likelihood of a variety of other possible impacts for which the method was not developed. Used properly, however, models can shed light on the importance of processes and variables to watershed behavior and treatment effects, but have limited value for precisely predicting watershed behavior (Reid, 1993). A large amount of data generally is required for

modeling, and its acquisition can involve intensive monitoring. Data analysis also can be complex, and these factors have kept the use of models very limited (MacDonald, 1997).

Slightly less complicated than modeling would be an analysis involving a broad-scale assessment of previous management activities. Such a method would use one or more management indices to assess the relative likelihood of a cumulative effect, rather than explicitly modeling cause-and-effect (MacDonald, 1997). The *EPA Synoptic Approach* and the *Washington State Watershed Analysis Method* (described below) are examples of this level of analysis.

Another approach for assessing cumulative effects consists of a collection of procedures used to evaluate a variety of impacts. A relevant subset of impacts is generally considered. This approach provides flexibility in determining what impacts will be considered, but it provides no guidance on determining which impacts should be evaluated (Reid, 1993). The *Water Resources Evaluation of Non-point Silvicultural Sources* (WRENSS) (described below) method is an example of a procedure-based approach.

A third general approach consists of a checklist of items to consider during an assessment. A checklist provides guidance in determining what impacts to evaluate but does not provide methods for doing so (Reid, 1993). Checklists are useful for (1) identifying which issues to look at in more detail, (2) helping to ensure that a range of issues are considered, (3) providing a simple means to address the issue of cumulative effects assessment. Disadvantages associated with checklists include the strictly qualitative nature of the assessments, their lack of repeatability, and their lack of documentation (MacDonald, 1997). The California Department of Forestry questionnaire (described below) is an example of a checklist assessment method.

Each approach has its strengths and weaknesses, and a workable approach should be a combination of these separate approaches. For example, a checklist or expert system could be used to guide users through a decision tree to identify the impacts to be considered, and then a set of procedures could be selected to address them (Reid, 1993). Modeling could be employed to assess the sensitivities of the watershed to various treatment scenarios.

Three techniques that have been developed for assessing cumulative effects are described below.

EPA The Synoptic Approach

The Synoptic Approach was developed by EPA for the evaluation of cumulative effects on wetlands for section 404 permit review. It does not provide a precise, quantitative assessment of cumulative effects, but is used to rate cumulative effects on resources of interest (Berg et al., 1996). The Synoptic Approach has two major steps—definition of the synoptic indices and selection of landscape indicators.

Synoptic Indices

Four synoptic indices are used for assessing cumulative effects and relative risk—function, value, functional loss, and replacement potential. The *function* index refers to the total amount of a particular function a wetland provides within a landscape

subunit without consideration of the ecological or social benefits of that function. Landscape elements function within landscapes through physical, chemical, and biological processes to provide habitat, cleanse water, prevent flooding, and perform other functions. The *value* index refers to the value of ecological functions with respect to public welfare. Tangible benefits (e.g., hunting, camping, timber, carbon dioxide sequestration) and intangible benefits (e.g., aesthetic, existence value) can both be included, as well as future value as the future benefit of the functions performed. Note that the value index does not represent economic value since market factors are not considered. The *functional loss* index represents cumulative effects on a particular valued function that have occurred within a landscape subunit. A complete loss, where an ecosystem element is changed into something else entirely, is a *conversion*. A partial loss, where ecosystem element type is the same but functioning is altered, is *degradation*. In the course of a cumulative effects assessment, future loss is considered per the Council on Environmental Quality's regulations (40 CFR 1508.7). Functional loss depends on the characteristics of a particular effect, including the type of effect; its magnitude, timing, and duration; and ecosystem resistance, or the sensitivity of the ecosystem element to disturbance. The *replacement potential* index represents the ability to replace an ecosystem element and its valued functions. Functional replacement through ecological restoration or natural recovery are both considered. Protection of ecosystem elements and functions is critical for risk reduction if their replacement potential is judged to be low (USEPA, 1992).

Landscape Indicators

Landscape indicators are first-order approximations that represent some particular synoptic index. Quantifying specific synoptic indices for large landscape subunits would be difficult if not impossible, so the Synoptic Approach uses landscape indicators of actual functions, values, and effects (USEPA, 1992).

As an example, a particular management concern might be nonpoint source sediment loading to streams. Nonpoint source sediment loading would then be the synoptic index used in the Synoptic Approach. Since it would be difficult to quantify this over a large area, total area harvested might be chosen as a landscape indicator for forest harvesting. Total harvested area would be the data used to determine cumulative nonpoint source sediment loading effects on the area of concern.

The Synoptic Approach is an ecologically based framework in which locally relevant information and best professional judgment are combined to address cumulative effects. It is not, however, meant to be used to assess the cumulative effects of specific actions. Rather, it is really meant to be used to augment site-specific review processes and to improve best professional judgment. It is probably most effectively used at extremely large landscape scales, such as the state level (Berg et al., 1996). The approach is valuable because it is flexible enough to cover a broad spectrum of management objectives and constraints—the specific synoptic indices and landscape indicators used in an application can be chosen based on the particular goals and constraints of the assessment—and it certainly need not be limited to assessing effects on wetlands. The process allows managers to weigh the need for precision against the constraints of time, money, and information (USEPA, 1992).

Washington State Watershed Analysis

The Washington State Watershed Analysis method is used to develop forest plans for individual watersheds based on current scientific understanding of the significant links between physical and biological processes and management activities. The first step in use of the method is screening a watershed to qualitatively define and assess areas of sensitivity to environmental change within the watershed. If any area is found to be sensitive, then the area and the causal mechanism must be addressed by a management plan appropriate to the problem. The management plan will define more precisely the potential effects of management actions and management alternatives. The method uses separate assessment modules for mass wasting, surface erosion, hydrologic change, riparian function, stream channel assessment, fish habitat, water supply/public works, and routing through the fluvial system (Berg et al., 1996).

The Washington State Watershed Analysis process is a collaborative one that involves both scientists and managers, and its products generally are area-specific management prescriptions and monitoring recommendations (Berg et al., 1996).

Water Resources Evaluation of Non-point Silvicultural Sources (WRENSS)

The WRENSS is a process-based approach to evaluating timber management impacts (Reid, 1993). It consists of a series of procedures for evaluating separate impacts, though it is not intended specifically to address CEs. The original focus of the method was water quality and consideration of the effects of timber management and roads. While its procedures do not address resources other than water quality, it would be possible to add additional methods to evaluate impacts on particular resources and to assess the effects of other land uses. Use of the method can be complex and time consuming.

The method is based on computer simulation modeling that delivers graphs and tables as results that are used to estimate changes in evapotranspiration, flow duration, and soil moisture from different logging plans. Temperature changes are incorporated using a separate model, the Brown model, and sediment modules include methods for estimating surface erosion, ditch erosion, landsliding, earthflow activity, sediment yield, and channel stability.

Application of the method to CE analysis would require the identification of likely environmental changes generated by a project, likely downstream impacts, and the mechanisms generating them.

California Department of Forestry Questionnaire

The California Department of Forestry and Fire Protection developed a questionnaire for use by registered professional foresters to assess potential cumulative watershed effects (CWE) from timber management. Completion of the questionnaire involves a four-step process: (1) perform a resource inventory in the assessment area; (2) judge whether the planned timber operation is likely to produce changes to each of those resources; (3) identify the effects of past or future projects; and (4) judge whether significant cumulative effects are likely from the proposed operation. Onsite and downstream beneficial uses, existing channel conditions, and adverse effects from past projects are identified and listed during the first step. The area for analysis is one of manageable size

relative to the timber harvest—usually an order 3 or 4 watershed. During the assessment, the user rates the magnitude of a variety of potential effects from the proposed and future projects, and combined past, present, and future projects. The assessment serves as an indicator of need for further review.

Responding to the questionnaire relies on the qualitative observations and professional judgment of the person filling out the forms. The questionnaire is designed to be used within the time constraints of the development of timber harvest plans and serves primarily as a checklist to be certain that all important issues have been considered. Its strength lies in its flexibility: the checklist can be easily altered to accommodate a wide variety of situations and harvesting conditions.

The California Department of Forestry questionnaire addresses a wide variety of uses and effects and includes many that are not related to water quality, e.g., recreational, aesthetic, biological, and traffic uses and values, but it provides only qualitative results. The questionnaire is the only CWE evaluation method that uses an assessment of more than one type of effect from more than one type of mechanism, and it is one of few that incorporates an evaluation of effects that accumulate due to past, present, and future actions (Berg et al., 1996).

Phased Approach to Cumulative Effects Assessment

MacDonald (2000), put forth a conceptual process for assessing cumulative effects. The process is an attempt to overcome some of the problems with other approaches to cumulative effects analysis (CEA), including problems in defining key issues, specifying the appropriate spatial and temporal scales, and determining the numerous interactions and indirect effects to analyze. The assessment is broken down into three phases: scoping, analysis, and management.

- **The scoping phase** is further broken down into steps in which the issues, resources, time scale, spatial scale, risk, and assessment effort are identified for the cumulative effects analysis. The analysis phase is likewise subdivided into five sub-steps.
- **In the analysis phase** researchers identify and analyze cause-and-effect mechanisms; natural variability and resource condition; past, present and future activities; relative impacts of past, present and future activities; and validity and sensitivity of the overall cumulative effects analysis.
- **The management phase** identifies possibilities for mitigation and restoration, as well as key data gaps and monitoring needs.

Figure 4-1 illustrates MacDonald's process for assessing cumulative effects.

The President's Council on Environmental Quality (CEQ) published guidelines for performing CEA (CEQ, 1997). The CEQ methodology is broken down into three groups of steps that are designed to be integrated into three components of an environmental impact assessment (EIA). The EIA components relevant to CEA are scoping, describing the affected environment, and determining the environmental consequences.

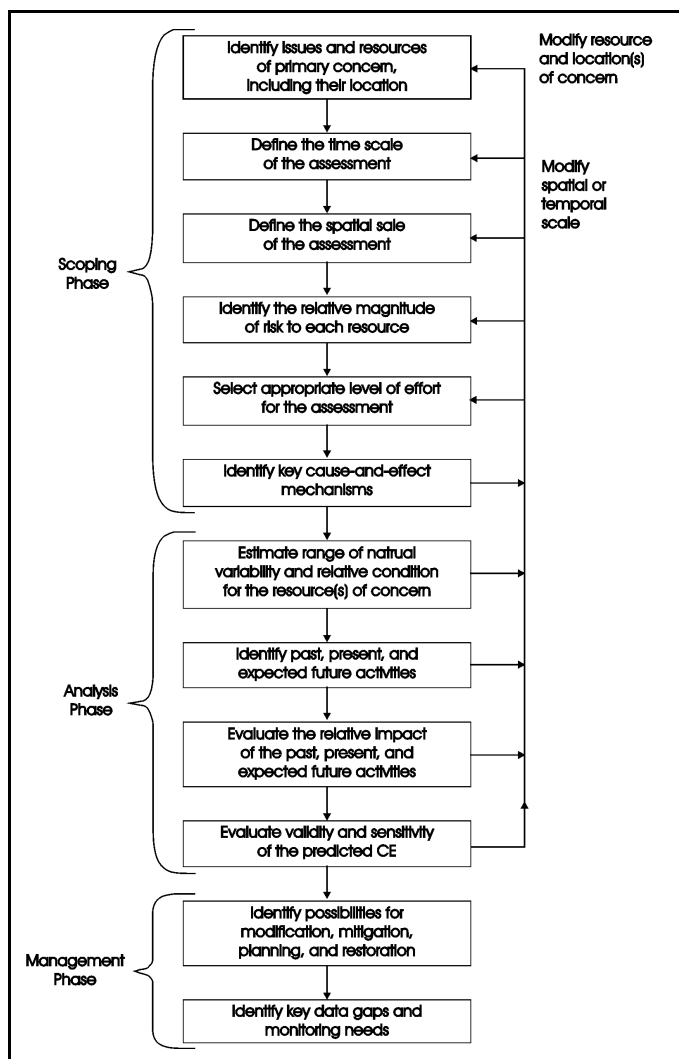


Figure 4-1. MacDonald's conceptual process for assessing cumulative effects.

- **In the scoping component** of an EIA, the CEA steps are to identify significant issues and define assessment goals; establish spatial boundaries of the CEA; establish temporal scale of the CEA; and identify other activities that affect natural and human communities.
- **The affected environment component** of the EA should incorporate the following CEA steps: characterize the resources, ecosystems and human communities and their resilience to stress; define stresses and regulatory thresholds for measuring stresses; and define baseline conditions for the area defined in the CEA.
- **The environmental consequences component** of the EIA should identify CEA cause-and-effect relationships between human activities and resources; determine the significance of cumulative effects; develop alternatives to minimize or mitigate significant cumulative effects; monitor cumulative effects and adapt management accordingly.

CEQ lists seven primary methods to develop baseline data and analytical models for cumulative effects analysis (CEA):

- **Questionnaires, interviews, and panels** to gather initial information
- **Checklists** to review important activities that may contribute to cumulative effects
- **Matrices** to tally cumulative effects
- **Networks and system diagrams** to qualitatively analyze effects of multiple activities on multiple resources in the analysis.
- **Modeling** to quantify the cause-and-effect relationships within the CEA.
- **Trends analysis** to use baseline data to extrapolate future cumulative effects
- **Overlay mapping (GIS)** to perform spatial analysis and identify areas of high and low impact.

Appendices to the CEQ report provide examples of each method and how it might be used in CEA. The report is available on the World Wide Web at <<http://ceq.eh.doe.gov/nepa/ccenepa/ccenepa.htm>>.

The MacDonald (2000) and CEQ (1997) guidelines share many similar components. The spatial and temporal boundaries of the CEA are defined first, along with the resources that will be impacted by cumulative effects. Detailed analysis of cause-and-effect relationships follows, and baseline data is developed to describe present conditions. Both methods include monitoring and mitigation steps toward the end of the process. MacDonald's framework differs from the CEQ methodology by including natural variability in systems, consideration of past and future activities, sensitivity analysis of predictive models, and an up-front determination on the level of effort that is appropriate for the assessment. MacDonald's refinements help address some of the hurdles to CEA implementation that have hampered past efforts.

Forest Watershed Management: An Example

The Umatilla National Forest, located in the Blue Mountains of southeast Washington and northeast Oregon, covers 1.4 million acres of diverse landscapes and plant communities (USDA-FS, 1999). The forest has some mountainous terrain, but mostly consists of v-shaped valleys separated by narrow ridges or plateaus. The landscape also includes heavily timbered slopes, grassland ridges and benches, and bold granite outcroppings. Elevations range from 1,600 to 8,000 feet above sea level.

The Forest is administered by the Forest Supervisors Office in Pendleton, Oregon, along with four Ranger Districts located in Pomeroy and Walla Walla, Washington, and Ukiah and Heppner, Oregon. The actual on the ground management of the forest resources is accomplished at the Ranger District level by the District Ranger and staff, while the Forest Supervisor oversees management and administration. The Forest is challenged daily with protecting both the productivity and the aesthetic values of the land. Managing to provide many resources, benefiting many people "for the long run" is the key principle guiding the Umatilla Management Team.

Because water from the Blue Mountains is important for so many uses, proper management of the watersheds in the Umatilla National Forest is strongly emphasized. The goals of the watershed management program are:

- To maintain streams that are cold, clean, and free of excessive sediments and human-caused pollution.
- To keep streambanks, channels, wetlands, and adjacent floodplains healthy.
- To restore damaged lands to their previous, productive condition.
- To maintain near-natural amounts of runoff water.

The Umatilla National Forest Plan includes important direction for achieving these goals. The plan envisions a basic three-point program for managing forest watersheds:

1. Inventory Basic Watershed Resources

Proper management of a forest watershed demands a good understanding of basic components—soil, water, climate, and vegetation. Managers at the Umatilla National Forest upgrade the resource information base for the forest by conducting the following inventories and surveys:

- Soil
- Water
- Fishery resources
- Potential watershed improvement projects
- Riparian zones (areas adjacent to streams and lakes)

These watershed surveys provide vital information for improving the management of surface water resources.

2. Apply Best Management Practices

The Umatilla National Forest has developed “best management practices”—policies, standards, and methods of operation designed to reduce harmful effects on water while still allowing use of other resources. Maintaining stream surface shading to prevent fish-bearing waters from overheating during the summer is an example of general practices applied throughout the forest. Others are developed specifically for a particular activity.

Forest managers work together in the project planning stages to identify the nature and risk of potential hazards to water resources. As a result, projects can be modified to avoid problem areas and reduce water resource damage.

The forest's watershed management program emphasizes the prevention of problems before they occur. However, it is sometimes necessary to treat watershed problems resulting from past practices. Such treatments might include restoring wet meadows, recontouring gullied lands, or stabilizing eroding streambanks.

Recently, a program to control and treat the acidic wastewater draining into a forest stream where salmon and steelhead spawn was begun in the Umatilla National Forest. These wastes, produced by abandoned gold mines, are now treated in man-made bogs, where toxic metals and other harmful substances are filtered out. Initial results have shown a dramatic recovery in water quality.

3. Monitor and Analyze Results

An extensive water-monitoring program has been developed for the Umatilla National Forest. It measures success in achieving the goal of maintaining healthy and abundant water resources. Monitoring stations are strategically placed at forest management projects to measure:

- Stream flow
- Water temperature
- Suspended sediment and turbidity

- Shape and condition of stream channels and riparian areas
- Precipitation, snow pack and other climatic factors
- The soil's ability to infiltrate and hold precipitation
- Physical, chemical and biological components of water quality

These measurements provide a better understanding of how management activities affect water resources and whether our efforts are effective in maintaining high water quality.

This chapter discusses monitoring the implementation and effectiveness of forestry management measures. For the most part, such monitoring is done either for research purposes or to assess compliance with regulatory requirements or recommendations. Therefore, it is usually the domain of universities or government agencies and this chapter is directed primarily at state agencies responsible for compliance with forestry regulations or nonpoint source pollution control regulations. Owners and managers of large forestland tracts are encouraged to work with state officials to develop a means of monitoring the implementation of BMPs on their lands to assess whether they are installed and maintained correctly and will function effectively, whether the state has a program of mandatory or voluntary forest practice BMP implementation.

Overview

Designing and legal implementing a state program of management practices for forest harvests and forest road construction cannot protect water quality unless the BMPs are implemented by those that actually harvest the timber or manage the land to be harvested. Monitoring the implementation of BMPs is a crucial element of any BMP program. Monitoring provides feedback on whether management practices are implemented as required or recommended by state and federal governments, on how the BMP program is received by harvesters and landowners, and on BMP design and use standards and specifications so they can be refined to be more useful and more effective.

Many states have implemented programs to monitor the implementation of forestry BMPs at harvest sites in conjunction with the passage of forest practice legislation or after a state has established a set of forest practice BMP recommendations. A review at the end of this chapter provides information about some of these programs. Fewer states monitor the effectiveness of management practices at protecting water quality as part of their BMP implementation monitoring programs. However, even a limited amount of effectiveness monitoring, such as under controlled conditions during experimental harvests, is important to ensure that BMP design specifications and standards are adequate to protect water quality and soils. Once it is determined that BMP that are installed according to state standards are actually effective, it might be acceptable to monitor only the implementation of BMPs to ensure that they are properly installed. It could then be assumed that they effectively protect water quality and forest resources. Without the initial information that properly implemented BMPs are effective, though, little can be said about the degree of water quality and forest resource protection provided by properly installed BMPs.

Monitoring Program Fundamentals

The most fundamental step in the development of a monitoring plan is to define the goals and objectives, or purpose, of the monitoring program. In general, monitoring goals are broad statements such as “to measure changes in fish spawning habitat” or “to measure

nutrient loading to streams adjacent to harvest sites.” Monitoring programs can be grouped according to the following general statements of purpose or expected outcomes:

- Describe status and trend
- Describe and rank existing and emerging problems
- Design management and regulatory programs
- Evaluate program effectiveness
- Respond to emergencies
- Evaluate the implementation of best management practices
- Evaluate the effectiveness of best management practices
- Validate a proposed water quality model
- Perform research

Unlike monitoring goals, monitoring objectives are more specific statements that can be used to add detail, including geographic scale, measurement variables, sampling methods, and sample size, to the monitoring design. Detailed monitoring program objectives enable the designer of the program to define precisely what data will be gathered in order to meet the management goals. Vague or inaccurate statements of objectives lead to program designs that provide too little or too much data, thereby either failing to meet management needs or costing too much.

Numerous guidance documents have been developed, or are in development, to assist resource managers in developing and implementing monitoring programs that address all aspects of monitoring design. Appendix A in *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (USEPA, 1997) presents a review of more than 40 monitoring guidances for both point and nonpoint source pollution. These guidances discuss virtually every aspect of nonpoint source pollution monitoring, including monitoring program design and objectives, sample types and sampling methods, chemical and physical water quality variables, biological monitoring, data analysis and management, and quality assurance and quality control.

Once the monitoring goals and objectives have been established, existing data and constraints are considered. A thorough review of literature pertaining to water quality studies previously conducted in the geographic region of interest can help determine whether existing data provide sufficient information to address the monitoring goals and what data gaps exist.

Identification of project constraints address financial, staffing, and temporal elements. Clear and detailed information is obtained on the time frame within which management decisions need to be made, the amounts and types of data that is to be collected, the level of effort needed to collect the necessary data, and equipment and personnel needed to conduct the monitoring. From this information it can be determined whether available personnel and budget are sufficient to implement or expand the monitoring program.

As with monitoring program design, the level of monitoring that will be conducted is largely determined when goals and objectives are set for a monitoring program, although there is some flexibility for achieving most monitoring objectives.

The overall scale of a monitoring program has two components—a temporal scale and a geographic scale. The temporal scale is the amount of time required to accomplish the program objectives. It can vary from an afternoon to many years. The geographic scale

can also vary from quite small, such as plots along a single stream reach, to very large, such as an entire river basin. The temporal and geographic scales, like a program's design and monitoring level, are primarily determined by the program's objectives.

If the main objective is to determine the current biological condition of a stream, sampling at a few stations in a stream reach over 1 or 2 days might suffice. Similarly, if the monitoring objective is to determine the presence or absence of a nonpoint source effect, a synoptic survey might be conducted in a few select locations. If the objective is to determine the effectiveness of a watershed forest management program for improving water quality conditions in streams, however, monitoring subwatersheds for 5 years or longer might be necessary. If the objective is to calibrate or verify a model, very intensive sampling might be necessary.

Depending on the objectives of the monitoring program, it might be necessary to monitor only the waterbody with the water quality problem or it might be necessary to include areas that have contributed to the problem in the past, areas containing suspected sources of the problem, or a combination of these areas. A monitoring program conducted on a watershed scale will include a decision about the watershed's size. The effective size of a watershed is influenced by drainage patterns, stream order, stream permanence, climate, number of landowners in the area, homogeneity of land uses, watershed geology, and geomorphology. Each factor is important because each has an influence on stream characteristics, although no direct relationship exists.

There is no formula for determining appropriate geographic and temporal scales for any particular monitoring program. Rather, once the objectives of the monitoring program have been determined, a combined analysis of them and any background information on the water quality problem(s) being addressed will make it clear what overall monitoring scale is necessary to reach the objectives.

Other factors that can be considered to determine appropriate temporal and geographic scales include the type of water resource being monitored and the complexity of the nonpoint source problem. Some of the constraints mentioned earlier, such as the availability of resources (staff and money) and the time frame within which managers need monitoring information, will also contribute to determination of the scale of the monitoring program.

For additional details regarding nonpoint source monitoring techniques, including chemical and biological monitoring, refer to *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (USEPA, 1997). This technical document focuses on monitoring to evaluate the effectiveness of management practices, but also includes approximately 300 references and summaries of more than 40 other monitoring guides. In addition, Chapter 8 of EPA's management measures guidance for section 6217 contains a detailed discussion of monitoring (USEPA, 1993).

Monitoring BMP Implementation

The implementation of management measures and BMPs can be tracked to determine the extent to which the measures are implemented on a harvest site, in a watershed, or in

another geographic area. Implementation and trend monitoring can be used to address the following goals:

- Determine the extent to which management measures and practices are implemented in accordance with relevant standards and specifications.
- Determine whether there has been a change from previous years in the extent to which management measures and practices are being implemented.
- Establish a baseline from which decisions can be made regarding the need for additional incentives for implementation of management measures.
- Measure the success of voluntary implementation efforts.
- Support workload and costing analyses for landowner assistance or regulatory programs.
- Determine the relative adoption rates of various management measures across different geographic areas.
- Determine the extent to which management practices are properly maintained and operated.

Methods to assess the implementation of management measures are a key focus of the technical assistance to be provided by EPA and NOAA under CZARA section 6217.

Implementation assessments can be done on several scales. Site-specific assessments can be used to assess individual management practices or management measures, and watershed assessments can be used to look at the cumulative effects of implementing multiple management measures. With regard to “site-specific” assessments, it is important to assess individual management practices at the appropriate scale for the practice of interest. For example, to assess the implementation of management measures or management practices for forest roads at harvest sites, only the roads at timber harvesting sites would need to be inspected. In this example, the scale would be a timber harvest area and the sites would be active and inactive roads at the harvest areas. To assess implementation of management measures and practices at streamside management areas, the proper scale might be a harvest area larger than 10 acres and the sites could be areas encompassed by buffer areas for 200-meter stretches of stream. For site preparation and forest regeneration, the scale and site might be an entire harvest site. Site-specific measurements can then be used to extrapolate to a watershed or statewide assessment. It is recognized that some studies might necessitate a complete inventory of management measures and practice implementation across an entire watershed or other geographic area.

Sampling design, approaches to conducting the evaluation, data analysis techniques, and ways to present evaluation results are described in EPA’s *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures—Forestry* (USEPA, 1997a), from which much of the text for this chapter has been borrowed. Chapter 8 of EPA’s management measures guidance for section 6217 contains a detailed discussion of techniques and procedures to assess implementation, operation, and maintenance of management measures (USEPA, 1993).

Monitoring BMP Effectiveness

By tracking management measures and water quality simultaneously, analysts gain the information necessary to evaluate the performance of the management measures implemented. Management measure tracking provides information on whether pollution controls are being implemented, operated, and maintained adequately. Only with such information is it possible to draw conclusions from water quality monitoring data about the effectiveness of management practices.

A major challenge in attempting to relate implementation of management measures to water quality changes is determining the appropriate land management attributes to track. For example, a “bean count” of the number of management measures implemented in a watershed has little chance of being useful in statistical analyses to relate water quality to land treatment since the count only remotely relates (i.e., a mechanism is lacking) to the measured water quality parameter (e.g., cobble embeddedness). Land treatment monitoring that relates directly to the pollutants or effects monitored at the water quality station is most useful. For example, the spacing of water bars relative to slope might be a more useful parameter to track than the number of miles of road constructed. Since the effect of management measures on water quality might not be immediate or implementation might not be sustained, information on other relevant watershed activities (e.g., urbanization, wildfire frequency and extent) is essential for the final analysis.

Management practice effectiveness has not been well documented on a watershed scale, particularly for watersheds with mixed land uses. Studies of management practice effectiveness have been done at the plot and field scales where specific treatments are used and compared to a control situation. Extrapolations from these data and studies using nonpoint source pollution models constitute most of the information available on a watershed scale. Actual data collection and management practice effectiveness determination on a watershed scale is more complex and, because of natural variability, it requires long periods of monitoring before management practice implementation so that a statistical minimum detectable change level can be established. The minimum detectable change is the minimum measurable change in a water quality parameter over time that is statistically significant, and it is a function of statistical tests, the number of samples taken per year, the number of years of monitoring, and the variates and covariates used in the analyses. An approach for watershed monitoring of management practice effectiveness, and the problems associated with the approach and with such studies in general, is discussed in Park and others (1994).

Appropriately collected water quality information can be evaluated with trend analysis to determine whether pollutant loads have been reduced or whether water quality has improved. Valid statistical associations drawn between implementation and water quality data can be used to indicate the following:

- Whether management measures have been successful in improving water quality in a watershed or recharge area.
- The need for additional management measures to meet water quality objectives in the watershed or recharge area.

Greater detail regarding methods to evaluate the effectiveness of land treatment efforts is provided in EPA's nonpoint source monitoring guidance (USEPA, 1997) and management measures guidance for section 6217 (USEPA, 1993).

Importance of BMP Monitoring

Researchers with the U.S. Forest Service reviewed State BMP implementation and monitoring programs and the results from those programs in 1994. At the time, twenty-one states were assessing BMP effectiveness. They found that the States had generally concluded that carefully developed and applied BMPs can prevent serious deterioration of water quality, and that most water quality problems were associated with poor BMP implementation. Water quality monitoring was determined to be essential to understanding the relationship between land disturbance and water quality, as it leads to improved understanding of the interaction of soils and topography with BMP implementation. BMP guidelines can be reassessed continually to make them more cost effective, and the more they can be specified, used, monitored, and fine tuned for specific circumstances, the more cost-effectively they can be used to protect water quality.

Quality Assurance and Quality Control

Quality assurance (QA) and quality control (QC) are commonly thought of as procedures used in the laboratory to ensure that all analytical measurements made are accurate. But QA and QC extend beyond the laboratory and are essential components of all phases and all activities within each phase of a nonpoint source monitoring project.

Definitions of Quality Assurance and Quality Control

Quality assurance is an integrated management system designed to ensure that a product or service meets defined standards of quality with a stated level of confidence. Quality assurance activities involve planning quality control, quality assessment, reporting, and quality improvement.

Quality control is the overall system of technical activities designed to measure quality and limit error in a product or service. A quality control program manages quality so that data meet the needs of the user as expressed in a quality assurance project plan.

Quality control procedures include the collection and analysis of blank, duplicate, and spiked samples and standard reference materials to ensure the integrity of analyses, as well as regular inspection of equipment to ensure it is operating properly. Quality assurance activities are more managerial in nature and include assignment of roles and responsibilities to project staff, staff training, development of data quality objectives, data validation, and laboratory audits. Such procedures and activities are planned and executed by diverse organizations through carefully designed quality management programs that reflect the importance of the work and the degree of confidence needed in the quality of the results.

Importance of QA/QC Programs

Although the value of a QA/QC program might seem questionable while a project is under way, its value will be quite clear after a project is completed. If the objectives of the project were used to design an appropriate data collection and analysis plan, all QA/QC procedures were followed for all project activities, and accurate and complete records were kept throughout the project, the data and information collected from the project should be adequate to support a choice from among alternative courses of action. In addition, the course of action chosen should be defensible based on the data and information collected. Development and implementation of a QA/QC program can require up to 10 to 20 percent of project resources (Cross-Smiecinski and Stetzenback, 1994), but this cost can be recaptured in lower overall costs due to the project's being well planned and executed. Likely problems are anticipated and accounted for before they arise, eliminating the need to spend countless hours and dollars resampling, reanalyzing data, or mentally reconstructing portions of the project to determine where an error was introduced. QA/QC procedures and activities are cost-effective measures used to determine how to allocate project energies and resources toward improving the quality of research and the usefulness of project results.

EPA Quality Policy

EPA has established a QA/QC program to ensure that data used in research and monitoring projects are of known and documented quality to satisfy project objectives. The use of different methodologies, lack of data comparability, unknown data quality, and poor coordination of sampling and analysis efforts can delay the progress of a project or render the data and information collected from it insufficient for decision making. QA/QC practices are best used as an integral part of the development, design, and implementation of a nonpoint source monitoring project to minimize or eliminate these problems.

Additional information on QA/QC can be found in Chapter 5 of EPA's nonpoint source monitoring guide (USEPA, 1997) and in EPA documents on QA/QC.

Review of State Management Practice Monitoring Programs

Objectives of the Audits

In general, most state audits of harvest sites or other types of forestry operations have as their primary objectives to assess compliance with BMP implementation guidelines and/or the effectiveness of BMPs at preventing soil erosion and protecting water quality and environmental health. Additionally, and because the process of collecting the implementation and effectiveness lends itself well to the collection of related information that can be quite useful to a state forestry department, many states also collect information that will help them:

- Identify problem areas where additional landowner training and education is needed to improve BMP implementation.
- Determine which BMP implementation standards and specifications need revision.
- Identify necessary improvements in the BMP monitoring program.

Information on landowner training is easily gathered during the audits if the landowner on whose property a harvest was done is included in the audit. Landowners can be contacted before the audit in most instances to obtain permission to enter their property, and they can be included either during the audit, when they can perhaps be valuable sources of information, or afterward during a discussion of results with the audit person or team.

Analysis of BMP implementation standards and specifications can be done effectively during an audit, or during an analysis of audit results after an annual audit has been completed, by comparing the implementation and effectiveness information gathered during the audit with state implementation specifications. For example, specifications may call for a recommended maximum distance between culverts on forest roads of a given slope. During the audits it might be noticed that, even where these specifications have been adhered to, erosion is unacceptable. It may then be recommended to lower the maximum distance, or it might be noticed that excessive erosion is related to a particular soil type, and a shorter distance might be recommended where this soil type occurs.

Audits can provide valuable information about the monitoring program, too. It might be discovered during the course of the audits that instances of particular types of effects to soils or water resources are increasing over the years. Or it might be recognized that certain forestry operations (e.g., prescribed burning or site preparation) might not be accounted for in the audits adequately enough to draw conclusions about effects to water resources. Information collected during the audits can be used to adjust the monitoring program to actual information needs.

Audits conducted by some states serve specific objectives beyond assessments of BMP implementation and effectiveness. A good example is South Carolina, which has designed the data collection aspect of its BMP implementation survey to permit the state to determine the effect of a number of variables on compliance with BMP standards. The variables investigated include:

- Physiographic region in which the harvest occurred
- Occurrence of a stream on the harvest site
- Percent slope at the harvest site
- Type of terrain at the harvest site
- Category to which the landowner belonged
- Use of cost share assistance for the harvest
- Landowner's familiarity with state BMPs
- Use of a site preparation contract
- Written requirement for the use of BMPs
- Involvement of a forester in the prescription and supervision of site preparation
- Size of the area being site-prepared for reforestation

Criteria Used to Choose the Audit Sites

States use a number of criteria to select sites for inclusion in BMP audits. Generally, the criteria exclude from the audits those sites where BMPs of interest would not likely have been used, where the types of effects of interest (e.g., to water quality) would be difficult to detect or nonexistent, and sites where detecting whether BMPs had been implemented would be difficult due to changes in site characteristics since their implementation. Other criteria ensure inclusion in the audits sites from different topographic or vegetative community areas or administrative jurisdictions (e.g., counties or state forest service regions).

The use of criteria result in a biased sample of audit sites, and thus the conclusions from the audits cannot be used to draw conclusions about all harvest sites in a state. But complete random sampling of harvest sites would limit the usefulness of the results more than biasing the selection of sites by the use of criteria. Not limiting the sites chosen for the audits would result in the inclusion of sites where harvests had occurred many years previously and physical evidence of BMP implementation would be undetectable, sites in areas where BMPs of interest (such as those related to SMZs) would not have been used, and would possibly result in not including portions of the state of interest to the state forestry agency. Therefore, it is important to use criteria to ensure that audit sites provide the information of interest.

The following are some of the criteria used by most states.

Geographic Distribution

Generally, an entire state is included in an audit by choosing a minimum number of sites per county. A minimum of one site per county is a common criterion, though if timber harvesting is limited to certain areas, a state might include only those counties in which timber was harvested during the time period of interest (see second criterion). The geographical distribution of audit sites might be related to the quantity of timber harvested in a county by ensuring that the latter is proportional to the number of sites chosen for the county. Some states select sites based on other geographic criteria:

- Indiana targeted a specific watershed, the Lake Monroe watershed, in its first BMP survey.
- Montana ensures that the geographic distribution of audit sites reflects the distribution of timber harvest ownership group.
- Tennessee ensures that all physiographic regions of the state are represented.

Time Since Harvest

The timber harvest or other management activity of interest (e.g., site preparation, road construction) is to have occurred within a specific period of time, generally 1 to 2 years, prior to the audit.

Minimum Size

Audit sites are generally no less than 5 to 10 acres, which ensures that BMP use would have been called for. A minimum volume of harvested timber is another way of ensuring the same.

- Montana's criterion for size is a harvested volume of 5,000 board feet (MBF) per acre or more for audit sites in the western portion of the state and a minimum volume of 3 MBF for audit sites in the eastern portion of the state.

Proximity to Watercourse

Most states insist that harvest sites have a stream (perennial or intermittent), lake, wetland, or pond of a certain size on or near them. The criterion might be that the watercourse is on the audit site, especially if a primary goal of the audit is to assess implementation of SMZ rules or guidelines, or within 200 to 500 feet of the audit site if water quality effects of harvest operations are of particular concern. States that are interested in overall BMP implementation might not care that audit sites be associated with surface waters.

- South Carolina does not use as a criterion that audit sites be associated with surface waters.

Representation of Ownership

Inclusion of all ownership groups (private non-industrial, industrial, federal, state, and local) can be a criterion for choosing sites, though generally audit sites are not specifically chosen to represent the ownership groups. If all ownership groups are to be included, states might only use this criterion if a minimum number of sites per ownership group is not reached using the other criteria. When this happens, sites from an over-represented ownership group or groups are randomly deselected and sites from the under-represented group are randomly selected from those of the desired ownership group that meet the other criteria.

- Montana ensures that the number of sites investigated from each ownership group is proportional to the volume of timber harvested by each group. A minimum of 5 sites per ownership class are chosen.

Randomness

While, as stated above, randomness is not an overriding concern in the design of BMP audits, many states do ensure that once the criteria are met, sites are then selected randomly.

- Florida selects sites for its audit by flying fixed-wing aircraft in a predetermined pattern over counties until the predetermined number of sites for the county is attained.

Audit Focus: BMP Implementation and BMP Effectiveness

Surveys are geared toward investigating either BMP implementation or BMP effectiveness or both of these. The nature of the silvicultural activity at any given site that is investigated determines which BMPs are appropriate for implementation at the site or required to be used, depending on whether BMP use is mandatory or voluntary. Sites are generally rated based on the BMPs that *should* have been used at the site. If a timber harvest plan was prepared prior to the harvest, or a road construction plan prepared prior to construction of a road and BMPs were included in the plan(s), then the survey might investigate whether the BMPs included in the plan were actually implemented.

Some states target a particular class or group of BMPs during their surveys. For instance, as mentioned under point #1, Montana specifically investigates compliance with the state law and rules for SMZs and the effectiveness of SMZs in protecting water quality, and South Carolina uses the survey to determine which of 11 variables affect BMP compliance.

Florida conducted a separate study to evaluate BMP effectiveness using biological criteria. The state used the information gained during the BMP implementation survey as a measure of BMP compliance at the sites evaluated for BMP effectiveness. It is essential to have an assessment of BMP implementation at a site where BMP effectiveness is to be investigated, since BMP effectiveness can only be assessed at sites where it is known that BMPs have been implemented.

Number of Sites Investigated

The number of sites investigated varies widely and depends on survey design, amount of silviculture activity in the state, and availability of resources (staff and money). If the results of the survey are to be analyzed statistically, then the number of sites investigated must be sufficient for this purpose. Some examples of the number of sites included in audits are:

- Florida assessed 202 sites in 51 counties in 1997.
- Indiana assessed 91 sites in the Lake Monroe watershed in its first audit.
- Montana maintains an audit goal of 45 new sites, plus reaudits from previous years. It assessed 47 new sites and conducted 11 reaudits in 1998, and had an average of 45 sites per year from 1990-1996.
- South Carolina assesses the number of sites necessary for proper statistical analysis of the results. In 1996 it audited 177 sites.
- Tennessee audited 200 sites in 1996. Routine inspections were conducted on 179 sites and 21 sites were audited as follow-ups to water quality complaints.

Number of BMPs Evaluated

The number of BMPs investigated at each site varies depending on the objectives of the survey and the number and types of BMPs recommended or required by the state. Surveys that target specific types of operations or locations, such as road construction or SMZs, generally involve investigations of fewer BMPs than surveys to assess the use of BMPs for all aspects of forest harvesting, from temporary road construction to site preparation for reforestation. The following examples highlight the variety that can exist in state audits.

- Florida assesses implementation of 100 practices in 14 BMP categories.
- Indiana assessed use of 58 individual BMPs in the Lake Monroe watershed.
- Montana audits as many as 46 BMPs and 10 SMZ practices at each audit site.
- South Carolina assesses compliance with BMPs in four categories in 1996: mechanical treatments, herbicide applications, prescribed burning, and minor drainage.
- Tennessee assessed 36 individual BMPs in 1996.

Composition of the Investigation Teams

An investigation “team” can range from one person to a team of 5 to 7 people with different specialties. Again, the composition of the survey team depends on the objectives of the survey. If BMP implementation is the only thing being investigated, then a state forester alone might be capable of conducting the survey. If, on the other hand, soil characteristics, erosion hazard, improvements in road construction techniques, water quality effects, or other more complex issues are also being investigated, then a team of individuals that represent the appropriate disciplines is generally used.

When one person conducts the surveys, generally the person is a state forester who is familiar with BMP standards for both implementation and effectiveness. When teams are used for the surveys, the state forester is accompanied by one or more specialists that represent fields such as watershed science, soil science, wildlife biology, hydrology, fisheries, and road engineering. Separate organizations might also be represented, such as environmental or conservation organizations and the logging industry. Where possible, the survey team is accompanied by the landowner on whose property the survey is being conducted, the logger who conducted the harvest, and the state forester who prepared the harvest plan, if applicable. Examples of what an audit “team” consists of in different states are provided below.

- Florida’s audits are conducted by a county forester accompanied, in most cases, by the state Department of Forestry’s watershed specialist.
- Indiana used an audit team of 4-5 people, some with multiple expertise. Members were chosen from among the following disciplines or employments: Idaho Department of Natural Resources forester, forestry industry, environmental community, landowner, planning and development staff, wildlife biologist, hydrologist, soil conservationist.
- Montana used 4 teams of 7 members, one team each for the northwest, west, central, and eastern parts of the state, in 1998. In previous years only 3 teams were used.

Team members were chosen from the following disciplines or affiliations: fisheries biology, forestry, hydrology, conservation group representative, road engineer, soil scientist, logging professional, and non-industrial private landowner.

- South Carolina uses 2-person teams composed of two representatives from the Forestry Commission—a forest hydrologist and the project forester for the harvest site.
- Tennessee’s audits are conducted by a Forestry Division forester.

BMP Implementation and Effectiveness Rating Systems

The implementation of individual BMPs is rated in one of two ways. A scale of implementation, usually from 0 to 5 or 0 to 3, is used to rate not only whether a BMP was implemented but also the quality of implementation. Alternatively, BMPs are rated simply as having been implemented, not implemented, or not applicable to the particular site.

Generally, all BMPs applicable to a site are rated individually and the site then receives an overall BMP implementation rating. The latter rating might be made using one of the two rating systems mentioned above or using a 3-tiered rating system of excellent, adequate, or inadequate. The overall site rating is usually derived as an average of the individual BMP ratings at the site. Low ratings for overall BMP implementation—for example zero to two on a 0-to-5 scale, zero on a 0-to-3 scale, and inadequate on a 3-tiered rating system—are indications that follow-up with the landowner or harvester is necessary or that further education and training might be helpful.

Even when only BMP implementation is being assessed, BMP effectiveness is often rated on a qualitative basis as an onsite assessment of whether, in the case of a low score or inadequate BMP implementation, there was a resultant risk to water quality. Risks to water quality are generally rated as simply being present or not.

When more than one team is responsible for the assessments and where teams are composed of many people, assessment training or a mock assessment is performed prior to the actual assessments to establish a degree of consistency in the ratings among members and teams. Assessments of adequacy of BMP implementation and risk to water quality can involve many subjective judgements, and going through a mock assessment prior to the actual assessments gives all team members a chance to discuss what constitutes adequate or proper implementation for the different BMPs. In addition, in many states, after a site assessment and while the assessment team is still on the site the team gathers to discuss the ratings of the individual team members and to arrive at an overall site rating. If any discrepancies or differences of opinion cannot be settled through discussion alone, the individual BMPs are revisited.

Sample rating systems used by some states are provided below.

In Indiana, BMP implementation is rated on a scale of 0 to 4, and the individual ratings carry the following meanings:

- 0 = practice not applicable
- 1+ = exceeded BMP guideline
- 1 = met BMP guideline
- 2 = minor departure from BMP guideline
- 3 = major departure from BMP guideline
- 4 = gross neglect of BMP guideline

BMP effectiveness is rated separately according to the following scale:

- 1+ = BMP implementation improved protection of the water resource
- 1 = BMP implementation provided adequate protection of the water resource
- 2 = An indirect and temporary (less than 1 year) effect to the water resource resulted
- 3 = An indirect and prolonged (more than 1 year) effect to the water resource resulted
- 4 = A direct and temporary effect to the water resource resulted
- 5 = A direct and prolonged effect to the water resource resulted

Montana's rating scale is similar but provides different interpretations of the individual ratings:

BMP implementation is rated on a scale of 5 (best) to 1 (worse):

- 5 = Operation exceeds requirements of BMP
- 4 = Operation meets requirements of BMP
- 3 = Minor departure from intent of BMP (small magnitude over a localized area or larger are with low potential for effect)
- 2 = Major departure from intent of BMP (large magnitude or BMPs repeatedly neglected)
- 1 = Gross neglect of BMP (risks to soil and water resources obvious with no evidence of an attempt to protect the resources)

BMP effectiveness is rated qualitatively using the following categories:

- Adequate = Small amounts of material eroded, but the material does not reach draws, channels, or a floodplain.
- Minor = Some material erodes and is delivered to draws but not to a stream.
- Major = Material erodes and is delivered to a stream or annual floodplain.
- Temporary = Caused effects lasting 1 year or less, or for no more than 1 runoff season.
- Prolonged = Caused effects lasting more than 1 year.

South Carolina's Forestry Commission rates individual BMPs as having been implemented or not (i.e., yes or no); each major category of BMPs as pass or fail; and overall compliance for a site as excellent, adequate, inadequate.

Tennessee rates individual BMPs as having been implemented or not, or as not applicable to the site, and assesses whether a risk to water quality resulted due to each BMP that was inadequately implemented.

Results of the Audits

Results of many state audits for BMP implementation and effectiveness indicate that BMPs are being implemented and, where implemented, they are effective in protecting soil from erosion and water quality. Implementation by landowners and harvesters can depend on many factors, such as how long a state has had a BMP program, how long the state has been monitoring BMP implementation, the effectiveness of a state's education and training outreach program for BMP implementation, and what type of BMP program (i.e., voluntary or mandatory) a state has.

Some recent results from states are provided below.

- | | |
|-----------------|---|
| Florida: | <ul style="list-style-type: none">* Statewide compliance rating of 96% in 1993- Up from compliance rating of 84% in 1981 |
| Indiana: | <ul style="list-style-type: none">* Overall implementation rating of 83% in 1996-1997 (the first BMP implementation survey in the state)* Compliance for implementation by landowner group:<ul style="list-style-type: none">- State & local public (88%)- Classified (86%)- Federal (85%)- Nonindustrial private (78%)- Industrial private had only 1 site in survey and could not be rated |
| Montana: | <ul style="list-style-type: none">* Application rating of 94% of all practices rated as meeting or exceeding implementation standards in 1998* Effectiveness rating of 96% of all practices rated as providing adequate protection in 1998* The state has had consistently higher ratings each year since inception of the ratings in 1990. |
| South Carolina: | <ul style="list-style-type: none">* Overall compliance with site preparation BMPs was 86% in 1996. Compliance with BMP categories were as follows:<ul style="list-style-type: none">- 92% compliance with mechanical site preparation BMPs- 70% compliance with prescribed burning BMPs- 88% compliance with herbicide application BMPs- 77% compliance with drainage BMPs |
| Tennessee: | <ul style="list-style-type: none">* Overall implementation rate of 63% during its first audit (in 1993) on 150 logging operations |

As mentioned above, South Carolina has structured its BMP audits to provide information on the influence that certain factors have on BMP implementation. Results

from South Carolina's 1996 audit indicated that four variables were significantly related to BMP compliance. Those variables were physiographic region (Southern Piedmont, Atlantic Coastal Plain, Southern Coastal Plain, Carolina Sandhills, and Blue Ridge Mountains), proximity to streams (sites with no drainage features versus those with perennial, intermittent, or ephemeral streams), percent slope (divided among sites with 0-5 percent slope, 6-10 percent slope, 11-20 percent slope, and 21 percent slope or more), and terrain type (sandhill, flatwood, Carolina bay, or upland clay hills). BMP compliance was found to be:

- Lower in Southern Piedmont sites than in other physiographic regions
- Higher for sites that had no natural drainage features present
- Lower on sites with slopes of 11 percent and greater
- Lower for sites in upland clay hills

The other variables that were investigated (see listing under Point #1) were found not to be significantly related to BMP implementation.

Best Management Practices Evaluation Program: U.S. Forest Service, Pacific Southwest Region

The U.S. Department of Agriculture, Forest Service, Pacific Southwest Region began implementing a Best Management Practice Evaluation Program (BMPEP) to monitor and evaluate BMP implementation and effectiveness in 1992 and the program continues today (USDA-FS, Pacific Region, 1992). The ultimate objective of the BMPEP is to constantly improve both the level of implementation and effectiveness of BMPs that are applied to protect water quality in the region's 18 national forests.

Five years of data collected from 1992 to 1997 include 2,345 randomly selected BMP evaluations and represent 28 different monitoring procedures. Each monitoring procedure was developed to evaluate BMP use for a specific aspect of forestry operations, including aspects such as streamside management zones, skid trails, landings, stream crossings, temporary roads, prescribed fire, and revegetation of surface disturbed areas. The data were collected from sites in all 18 of the Pacific Southwest Region's 18 national forests.

Percent implementation of planned, prescribed and/or required water quality protection measures and percent effectiveness of the BMPs, whether implemented or not, at meeting their objectives were rated for each of the 2,345 evaluations. All of the evaluation ratings were also combined to arrive at overall implementation and effectiveness ratings. Based on the 1992-1997 data, implementation ranged from 47 to 96 percent (average 83 percent) and effectiveness ranged from 40 to 97 percent (average 82 percent). A statistically significant difference between effectiveness results at sites

where BMPs were implemented and where they were not implemented was found for 21 of the 28 separate monitoring procedures.

How the Evaluations are Done

Observers rate the degree to which BMPs were implemented and effective for each monitoring procedure. BMP implementation assesses the extent to which planned, prescribed and/or required water quality protection measures were actually put in place on-site (that is, it asks the question *Did we do what we had planned to do?*). BMP effectiveness assesses the extent to which the practices met their objectives (it asks the question *Did it work?*). Effectiveness determinations are based on both observation (e.g., presence and frequency of rills, evidence of sediment transport to channels) and measurements (e.g., amount of ground cover, percent of stream shade). Poor effectiveness scores represent the potential for impairment of a beneficial use by the activity, rather than actual impairment. When poor implementation is noted, observers are asked to identify the reasons and suggest improvements. When poor effectiveness is noted, observers are asked to comment on the estimated degree and duration of any existing or potential effects.

A chi-square test is used to test differences in effectiveness scores between sites where BMPs were implemented and sites where BMPs were not implemented. The test results, combined with comments made by observers while they are at the evaluation site, enables conclusions to be drawn about BMP effectiveness. BMP effectiveness is also analyzed by reviewing individual evaluation results, especially results where one or more BMPs were implemented but not found to be effective. Such an outcome indicates problems with these BMPs or their implementation.

Important Points to Note

Effectiveness criteria focus on site-specific indicators, which in most cases represent potential effects to water quality rather than actual effects. For example, rill erosion observed on a road would be listed as poor effectiveness, though any sediment from the erosion site that does reach a stream might have anywhere from a negligible to serious effect.

Where low or poor effectiveness is recorded, the observer comments on the type, degree, and duration of existing or potential effects observed. These comments are extremely important for analysis and BMP improvement.

Some observations have yielded the outcome that a BMP has been implemented but is not effective. Such results are useful as they indicate shortcomings of BMPs, that a BMP might be inappropriate for a particular area, or that the BMP was implemented poorly. Some form of improvement is definitely indicated.

Practices with a high number of comments about the effects on water quality (potential or real) and/or high ratings of “implemented-not effective” were often those implemented close to water courses. Because of the greater potential of practices near

water courses to affect water quality, it is prudent to prescribe conservative BMPs in these locations to provide adequate water quality protection.

It is important for foresters in a particular area to review the specific results from that area and not to rely solely on the regional summary. A BMP found to be effective in one area is not guaranteed have the same effectiveness whenever and wherever it is applied. Forest-specific results are more indicative of the changes that can be made to improve BMP effectiveness in a particular locality.

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Readers are encouraged to contact their state department of forestry for information pertaining to BMPs for forestry in their state and region. In addition, some of the above guidances that represent a synthesis of current information are recommended for further reading and are marked with an asterisk ().*

Access road: A temporary or permanent road over which timber is transported from a loading site to a public road. Also known as a haul road.

Alignment: The horizontal route or direction of an access road.

Allochthonous: Derived from outside a system, such as leaves of terrestrial plants that fall into a stream.

Angle of repose: The maximum slope or angle at which a material, such as soil or loose rock, remains stable (stable angle).

Apron: Erosion protection placed on the streambed in an area of high flow velocity, such as downstream from a culvert.

Autochthonous: Derived from within a system, such as organic matter in a stream resulting from photosynthesis by aquatic plants.

Bedding: A site preparation technique whereby a small ridge of surface soil is formed to provide an elevated planting or seed bed. It is used primarily in wet areas to improve drainage and aeration for seeding.

Berm: A low earth fill constructed in the path of flowing water to divert its direction, or constructed to act as a counterweight beside the road fill to reduce the risk of foundation failure (buttress).

Borrow pit: An excavation site outside the limits of construction that provides necessary material, such as fill material for embankments.

Broad-based dip: A surface drainage structure specifically designed to drain water from an access road while vehicles maintain normal travel speeds.

Brush barrier: A sediment control structure created of slash materials piled at the toe slope of a road or at the outlets of culverts, turnouts, dips, and water bars.

Buck: To saw felled trees into predetermined lengths.

Buffer area: A designated area around a stream or waterbody of sufficient width to minimize entrance of forestry chemicals (fertilizers, pesticides, and fire retardants) into the waterbody.

Cable logging: A system of transporting logs from stump to landing by means of steel cables and winch. This method is usually preferred on steep slopes, wet areas, and erodible soils where tractor logging cannot be carried out effectively.

Check dam: A small dam constructed in a gully to decrease the flow velocity, minimize channel scour, and promote deposition of sediment.

Chopping: A mechanical treatment whereby vegetation is concentrated near the ground and incorporated into the soil to facilitate burning or seedling establishment.

Clearcutting: A silvicultural system in which all merchantable trees are harvested within a specified area in one operation to create an even-aged stand.

Contour: An imaginary line on the surface of the earth connecting points of the same elevation. A line drawn on a map connecting the points of the same elevation.

Crown: A convex road surface that allows runoff to drain to either side of the road prism.

Culvert: A metal, wooden, plastic, or concrete conduit through which surface water can flow under or across roads.

Cumulative effect: The impact on the environment that results from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such action.

Cut-and-fill: Earth-moving process that entails excavating part of an area and using the excavated material for adjacent embankments or fill areas.

DBH: Diameter at breast height; the average diameter (outside the bark) of a tree 4.5 feet above mean ground level.

Disking (harrowing): A mechanical method of scarifying the soil to reduce competing vegetation and to prepare a site to be seeded or planted.

Diversion: A channel with a supporting ridge on the lower side constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

Drainage structure: Any device or land form constructed to intercept and/or aid surface water drainage.

Duff: The accumulation of needles, leaves, and decaying matter on the forest floor.

Ephemeral stream: A natural channel that carries water only during and immediately following rainstorms and whose channel bottom is seldom below that local water table. Sometimes referred to as a dry wash.

Felling: The process of cutting down standing trees.

Fill slope: The surface formed where earth is deposited to build a road or trail.

Firebreak: Naturally occurring or man-made barrier to the spread of fire.

Fire line: A barrier used to stop the spread of fire constructed by removing fuel or rendering fuel inflammable by use of fire retardants.

Foam line: A type of fire line that incorporates the use of fire-resistant foam material in lieu of, or in addition to, plowing or harrowing.

Ford: Submerged stream crossing where the traffic surface is reinforced to bear intended traffic.

Forest filter strip: Area between a stream and construction activities that achieves sediment control by using the natural filtering capabilities of the forest floor and litter.

Forwarding: The operation of moving timber products from the stump to a landing for further transport.

Geotextile: A product used as a soil reinforcement agent and as a filter medium. It is made of synthetic fibers manufactured in a woven or loose nonwoven manner to form a blanket-like product.

Grade (gradient): The slope of a road or trail expressed as a percentage of change in elevation per unit of distance traveled.

Harrowing (disking): A mechanical means to scarify the soil to reduce competing vegetation and to prepare a site to be seeded.

Harvesting: The felling, skidding, processing, loading, and transporting of forest products.

Haul road: See *access road*.

Intermittent stream: A stream that flows only during the wet periods of the year or in response to snow

melt and flows in a well-defined channel. The channel bottom may be periodically above or below the local water table.

Landing (log deck): A place in or near the forest where logs are gathered for further processing, sorting, or transport.

Leaching: Downward movement of a soluble material through the soil as a result of water movement.

Logging debris (slash): The unwanted, unutilized, and generally unmerchantable accumulation of woody material, such as large limbs, tops, cull logs, and stumps, that remains as forest residue after timber harvesting.

Merchantable: Forest products suitable for marketing under local economic conditions. With respect to a single tree, it means the parts of the bole or stem suitable for sale.

Mineral soil: Soil that contains less than 20 percent organic matter (by weight) and contains rock less than 2 inches in maximum dimension.

Mulch: A natural or artificial layer of plant residue or other materials covering the land surface that conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Mulching: Providing any loose covering for exposed forest soils, such as grass, straw, bark, or wood fibers, to help control erosion and protect exposed soil.

Muskeg: A type of bog that has developed over thousands of years in depressions, on flat areas, and on gentle to steep slopes. These bogs have poorly drained, acidic, organic soils supporting vegetation that can be (1) predominantly sphagnum moss; (2) herbaceous plants, sedges, and rushes; (3) predominantly sedges and rushes; or (4) a combination of sphagnum moss and herbaceous plants. These bogs may have some shrub and stunted conifers, but not enough to classify them as forested lands.

Ordinary high water mark: An elevation that marks the boundary of a lake, marsh, or streambed. It is the highest level at which the water has remained long enough to leave its mark on the landscape. Typically, it is the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial.

Organic debris: Particles of vegetation or other biological material that can degrade water quality by decreasing dissolved oxygen and by releasing organic solutes during leaching.

Outslope: To shape the road surface to cause runoff to flow toward the outside shoulder.

Patch cutting method: A silvicultural system in which all merchantable trees are harvested over a specified area at one time.

Perennial stream: A watercourse that flows throughout a majority of the year in a well-defined channel and whose bottom (in rainfall dominant regimes) is below the local water table throughout most of the year.

Persistence: The relative ability of a pesticide to remain active over a period of time.

Pioneer roads: Temporary access ways used to facilitate construction equipment access when building permanent roads.

Prescribed burning: Skillful application of fire to natural fuels that allows confinement of the fire to a predetermined area and at the same time produces certain planned benefits.

Raking: A mechanical method of removing stumps, roots, and slash from a future planting site.

Regeneration: The process of replacing older trees removed by harvest or disaster with young trees.

Residual trees: Live trees left standing after the completion of harvesting.

Right-of-way: The cleared area along the road alignment that contains the roadbed, ditches, road slopes, and back slopes.

Riprap: Rock or other large aggregate that is placed to protect streambanks, bridge abutments, or other erodible sites from runoff or wave action.

Rut: A depression in access roads made by continuous passage of logging vehicles.

Salvage harvest: Removal of trees that are dead, damaged, or imminently threatened with death or damage in order to use the wood before it is rendered valueless by natural decay agents.

Sanitation harvest: Removal of trees that are under attack by or highly susceptible to insect and disease agents in order to check the spread of such agents.

Scarification: The process of removing the forest floor or mixing it with the mineral soil by mechanical action preparatory to natural or direct seeding or the planting of tree seedlings.

Scour: Soil erosion when it occurs underwater, as in the case of a streambed.

Seed bed: The soil prepared by natural or artificial means to promote the germination of seeds and the growth of seedlings.

Seed tree method: Removal of the mature timber in one cutting, except for a limited number of seed trees left singly or in small groups.

Selection method: An uneven-aged silvicultural system in which mature trees are removed, individually or in small groups, from a given tract of forestland over regular intervals of time.

Shearing: A site preparation method that involves the cutting of brush, trees, or other vegetation at ground level using tractors equipped with angles or V-shaped cutting blades.

Shelterwood method: Removal of the mature timber in a series of cuttings that extend over a relatively short portion of the rotation in order to encourage the establishment of essentially even-aged reproduction under the partial shelter of seed trees.

Silt fence: A temporary barrier used to intercept sediment-laden runoff from small areas.

Silvicultural system: A process, following accepted silvicultural principles, whereby the tree species constituting forests are tended, harvested, and replaced. Usually defined by, but not limited to, the method of regeneration.

Site preparation: A silvicultural activity to remove unwanted vegetation and other material, and to cultivate or prepare the soil for regeneration.

Skid: Short-distance moving of logs or felled trees from the stump to a point of loading.

Skid trail: A temporary, nonstructural pathway over forest soil used to drag felled trees or logs to the landing. Skid trails may either be constructed or simply develop due to use depending on the terrain.

Slash: See *logging debris*.

Slope: Degree of deviation of a surface from the horizontal, measured as a numerical ratio, as a percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second number is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 percent slope. Expressed in degrees, the slope is the angle from the horizontal plane, with a 90 degree slope being vertical (maximum) and a 45 degree slope being a 1:1 slope.

Stand: A contiguous group of trees sufficiently uniform in species composition, arrangement of age classes, and condition to be a homogeneous and distinguishable unit.

Streamside management area (SMA): A designated area that consists of the stream itself and an adjacent area of varying width where management practices that might affect water quality, fish, or other aquatic resources are modified. The SMA is not an area of exclusion, but an area of closely managed activity. It is an area that acts as an effective filter and absorptive zone for sediments; maintains shade; protects aquatic and terrestrial riparian habitats; protects channels and streambanks; and promotes floodplain stability.

Tread: Load-bearing surface of a trail or road.

Turnout: A drainage ditch that drains water away from roads and road ditches.

Water bar: A diversion ditch and/or hump installed across a trail or road to divert runoff from the surface before the flow gains enough volume and velocity to cause soil movement and erosion, and deposit the runoff into a dispersion area. Water bars are most frequently used on retired roads, trails, and landings.

Watercourse: A definite channel with bed and banks within which concentrated water flows continuously, frequently or infrequently.

Windrow: Logging debris and unmerchantable woody vegetation that has been piled in rows to decompose or to be burned; or the act of constructing these piles.

Yarding: Method of transport from harvest area to storage landing.

Appendix A
Forestry Resources

EPA Forestry Resources

- *Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska.* EPA910991001. <http://www.epa.gov/ncepihom/Catalog/EPA910991001.html>

The above document is available from U.S. EPA Public Information Center - S1043, 1200 Sixth Avenue, Seattle, WA 98101; phone 206-553-1200, fax 206-553-1049.

- *Summary of current state nonpoint source control practices for forestry.* EPA841S93001. <http://www.epa.gov/ncepihom/Catalog/EPA841S93001.html>
- *Water quality effects and nonpoint source control for forestry: An annotated bibliography.* EPA841B93005. <http://www.epa.gov/ncepihom/nepishom/tips.html>
- *Nonpoint pointers: Managing nonpoint source pollution from forestry, pointer no. 8.* EPA841F96004H. <http://www.epa.gov/ncepihom/Catalog/EPA841F96004H.html>
- *Techniques for tracking, evaluating, and reporting the implementation of nonpoint source control measures: Forestry.* <http://www.epa.gov/ncepihom/Catalog/EPA841B97009.html>. EPA841B97009.
- *Evaluating the effectiveness of forestry best management practices in meeting water quality goals or standards* (bound copy). <http://www.epa.gov/ncepihom/Catalog/EPA841B94005B.html>. EPA841B94005B.
- *Evaluating the effectiveness of forestry best management practices in meeting water quality goals or standards* (3-hole punch). <http://www.epa.gov/ncepihom/Catalog/EPA841B94005A.html>. EPA841B94005A.

The above are available from the National Center for Environmental Publications and Information, P.O. Box 42419, Cincinnati, OH 45242-2419; phone 800-490-9198; fax 513-489-8695; or online at <http://www.epa.gov/ncepihom>.

- *Facts about silvicultural activities in wetlands.* EPA904F91100. <http://www.epa.gov/ncepihom/Catalog/EPA904F91100.html>

The above is available from U.S. EPA, Region 4, Library, 345 Courtland Street, N.E., Atlanta, GA 30365; phone 404-347-4216.

- *EPA Nonpoint Source News-Notes:* published by EPA quarterly and available on the Internet. Occasionally has articles of interest to foresters and forest land owners. Recent articles have included:

Scientist Links Nutrient Runoff with Forest Defoliation (No. 51, April/May 1998)
New Management Policies Proposed for National Forest Road System (No. 52, July/August 1998)
Urban Forests Decline; Runoff Increases in Puget Sound Area (No. 53, September/October 1998)
Working Buffer Strips Provide Profit and Protection (No. 54, November 1998)
Report Lists Communities Suffering Flood Losses (No. 54, November 1998)
Watershed Management Helps Lake Quality (No. 54, November 1998)
Applying a Watershed Model to Reduce Nonpoint Source Runoff (No. 56, February/March 1999)
Texas Forest Service Teaches Loggers about BMPs and Water Quality (No. 56, February/March 1999)

Nine Salmon Listed in Urban Pacific Northwest (No. 57, May 1999)

Riparian Forest Wildlife Guidelines for Landowners and Loggers (No. 58, July 1999)

Getting Started With TMDLs (No. 59, November 1999)

Articles from the *Nonpoint Source News-Notes* series can be obtained from the Internet at:

<http://www.epa.gov/owow/info/NewsNotes/>

- Other EPA publications related to forests and forestry can be found at the EPA publications website by searching on “forest” or “forestry”: <http://www.epa.gov/ncepihom/catalog.html>

Resources for Non-Industrial Private Forest (NIPF) Landowners:

The Sustainable Forestry Partnership has a web page devoted to Nonindustrial Private Forest Landowners:

<http://sfp.cas.psu.edu/nipf.htm>

USDA Forest Service—List of Publications, Resources

The USDA Forest Service, Washington Office and regional offices have a number of publications and other resources related to forestry. Lists of available publications, some of which are available electronically, and ordering information can be viewed at the Internet sites of the respective offices. Access to the Washington, DC office and the regional office Internet sites can be gained through the Internet site for publications for the USDA Forest Service:

<http://www.fs.fed.us/links/products.shtml>

The documents of the *Water-Road Interaction Technology Series*, published by the U.S. Forest Service, San Dimas Technology and Development Center, San Dimas, California, are available at:

<http://www.stream.fs.fed.us/water-road>

Other resources that will be of interest to forestland owners and that are available electronically include:

- FishXing (software and learning system for fish passage through culverts):
<http://www.stream.fs.fed.us/fishxing>
- Forest Service Roads Analysis Process:
<http://www.fs.fed.us/news/roads/DOCSroad-analysis.shtml>
- Forest Roads Science Synthesis:
<http://www.fs.fed.us/news/roads/science.pdf>

Appendix B

Sources of Technical Assistance

SOURCES OF TECHNICAL ASSISTANCE

U. S. Department of Agriculture
Natural Resources Conservation Service
P.O. Box 2890 Washington, D.C. 20013

U.S. Department of Interior
Fish and Wildlife Service
Public Affairs Office
18th and C Streets, N.W.
Washington, DC 20240

U.S. Department of the Interior
Geological Survey
12201 Sunrise Valley Drive
Reston, Virginia 22092

U.S. Forest Service
Office of Information
Room 3238
P.O. Box 2417
Washington, DC 20013

U.S. Department of Commerce
National Climatic Center
Federal Building
Asheville, North Carolina 28801
(Attn: Publications)

American Forest Institute
1619 Massachusetts Ave., N.W.
Washington, DC 20036

American Forests
P.O. Box 2000
Washington, D.C.
20013-2000

Association of Consulting Foresters of America
5400 Grosvenor Lane, Suite 300
Bethesda, Maryland 20814

International Society of Arboriculture
P.O. Box 71
5 Lincoln Square
Urbana, Illinois 61801

International Society of Arboriculture
P.O. Box GG
6 Dunlap Court
Savoy, Illinois 61874

National Arbor Day Foundation
100 Arbor Avenue
Nebraska City, Nebraska 68410

National Arborist Association
P.O. Box 1094
Amherst, New Hampshire 03031-1094

National Association of State Foresters
Hall of the States, #526
444 North Capital Street, N.W.
Washington, D.C. 20001

National Urban Forest Council
c/o American Forests
P.O. Box 2000
Washington, D.C. 20013

Soil and Water Conservation Society
7515 Northeast Ankeny Road
Ankeny, Iowa 50021-9764

American Sod Producers Association, Inc.
9th and Minnesota Streets
Hastings, Nebraska 68901

The IPM Practitioner
PO Box 7414
Berkeley, California 94707
(510) 524-2567

Directory of Least-Toxic Pest Control Products

Pesticide Hot Line (Autovon 584-3773)
U.S. Army Environmental Hygiene Agency
Pest Management and Pesticide
Monitoring Division
Aberdeen Proving Ground, Maryland 21005

The Internet site of the *National Association of State Foresters* —
<http://205.185.177.133/index.html> — has links to
many forestry resources, including:

- State Forestry Statistics
- State Forester Directory
- State Forester Home Pages
- State and Private Forestry Programs
- Other Forestry Links

Appendix C

Forest Management Certification Programs

FOREST MANAGEMENT CERTIFICATION PROGRAMS

Forest Management and Forest Product Certification

In the last 10 years, forest management monitoring has been extended beyond an evaluation of whether best management practices have been implemented according to state or federal specifications for the protection of habitat values and water quality to encompass ecological, social, and economic values. Independent organizations offer certification of forest management and forest products to forestry operations managed according to an internationally accepted set of criteria for sustainable forest management (Crossley, 1996). The principles and criteria of sustainable forestry are general enough to be applicable to tropical, temperate, and boreal forests, but the standards used to certify individual operations are sufficiently site- and region-specific for critical evaluation of individual forests and forestry operations.

In order to be certified, forest management must adhere to principles of resource sustainability, ecosystem maintenance, and economic and socioeconomic viability. Resource sustainability means that harvesting is conducted such that the forest remains productive on a yearly basis. Large scale clearcutting, for instance, such that the forest would have to remain idle and unproductive for many years, would generally not be acceptable. Ecosystem maintenance means that the ecological processes operating in a forest continue to operate without interruption and the forest's biodiversity is maintained. The principle implies that harvesting does not fundamentally alter the nature of the forest. Economic and socioeconomic viability incorporate the two previous principles and imply that forest operations are sufficiently profitable to sustain operations from year to year and that social benefits provided by a forest, such as existence and recreational value, are also maintained over the long term. Economic and socioeconomic viability are incentives for local people to sustain the ecosystem and resources of the forest (Evans, 1996).

Development of guidelines for sustainable forest management began with the International Tropical Timber Organization (ITTO). In 1989, the ITTO Council requested that "best practice" guidelines for sustainable management of natural tropical forests be developed. Soon afterward, global efforts to define and implement "sustainable forest management" began with the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in 1992. Non-binding "Forest Principles" were endorsed by more than 170 countries attending that conference, though many attending countries hoped that a binding "Forests Convention," similar to those for biodiversity and ozone layer protection, would be endorsed. Since Rio, dozens of fora, groups, and processes have been developed to define and evaluate sustainable forest management.

The movement to evaluate forest management and forest products based on principles of sustainable management is an expansion of focus as more knowledge is gained about forest ecological processes and the impacts, both local and global, of poorly managed forests on ecological systems and, consequently, on human economic and social systems. The expansion is similar to the natural expansion of EPA's focus in the realm of water pollution control from point sources of pollution to nonpoint sources of pollution to the present focus on watershed processes. Progress gained in overcoming one problem (e.g., point sources of water pollution) highlight the impacts of other problems (e.g., nonpoint sources of water pollution) and the search for overcoming these problems naturally expands to encompass the new problems that are highlighted. As more sources of impact are recognized, the focus must expand to encompass them. Thus, while water pollution control has become focused on watershed processes and activities occurring

within watersheds, forest management is naturally expanding to encompass the processes dependent on the forest (i.e., ecological, social, and economic) and which can be severely limited by poor management.

Two steps are involved in certifying wood products. First, forest management is certified as sustainable according to an evaluation based on accepted principles of sustainable forest management. Various organizations refer to this certification process as forest certification, forest management auditing, or timber certification. Evaluations are always conducted by a third, independent party. The second step is wood-product certification, or forest product labeling. Again, a third party follows the harvested wood through the manufacturing and product development processes, a "chain-of-custody" inspection process, to certify and label the products created from wood harvested from a "sustainable" forestry operation. Both types of certification are currently carried out by both for-profit companies and not-for-profit organizations that are predominantly based in the United States and the United Kingdom. Well known examples are Scientific Certification Systems (SCS) and the Rainforest Alliance's Smart Wood Program (Evans, 1996). These groups are active in the United States and their evaluation processes are described below.

Forest Conservation Program - Scientific Certification Systems (US)

The Forest Conservation Program (FCP) was established by Scientific Certification Systems (SCS) in 1991 as a certification program for sustainable forestry. SCS has certified forests in California (Collins Pine Almanor Forest), Pennsylvania (Collins Pennsylvania Forest), Wisconsin (Menominee Forest), and Mexico.

The FCP uses an evaluation process based on the program elements mentioned above: resource sustainability, ecosystem maintenance, and economic and socioeconomic viability. Each program element is evaluated according to a set of criteria that best represents appropriate benchmarks of sustainable forest management in the region of interest. Timber resource sustainability is evaluated based on criteria relating to how fully-stocked stands are, growing conditions, age and/or size class distribution (even-aged management or uneven-aged management), and whether management allows for sustained yearly harvests and avoids idle years.

The forest ecosystem maintenance element is evaluated based on criteria relating to whether non-timber resource values are a part of management and the extent to which natural ecosystem conditions and processes are altered by harvests. The economic and socioeconomic element is concerned with the overall economic viability of forest operations and the socioeconomic impacts of operations on harvesters and the local community.

The FCP program is designed to provide a quantitative and qualitative approach to certification. Forest evaluations are based on five sources of information. The landowner; investigations of information related to harvesting operations (e.g. timber inventory data, timber management plans, business management plans, and employee records); field sampling (e.g., wildlife surveys); field reviews; and interviews with employees, contractors, and individuals and organizations from the community.

SCS provides two levels of recognition under the FCP program, "Well-managed" and "State-of-the-Art Well-managed." Well-managed forests meet FCP standards for sustainable management as described below. "State-of-the-Art Well-managed" forests rank in the top 10 percent of all forests evaluated under the FCP program.

Evaluations are conducted by an evaluation team that consists of persons with expertise in relevant disciplines, such as forestry, wildlife biology, ecology, and economics. Persons with local or regional expertise are incorporated into evaluation teams and all evaluations are peer reviewed. Periodic monitoring of the forest after initial evaluation, lasting 1 to 3 years, is required as part of certification. Evaluation criteria are selected and weighted to account for regional circumstances.

Each criterion is given a ranking from 1 to 100 based on its perceived importance to sustainable management of the particular forest. Forest management is then scored by the evaluation team according to the chosen criteria. Sixty points on a normalized 100-point scale is the “failure threshold” for each criterion. Forests that receive 60 points or more in all three categories are designated “Well-managed.” Forests among the top 10 percent of all SCS-rated forests are given the “State-of-the-Art” designation. The designation given to the forest management operation is also applied to products from wood harvested from the certified forest.

The program is practical and feasible for forest managers to implement because standards of what constitutes good performance and what leads to failure to attain certification for each criterion are clearly described and adaptable for local or regional circumstances. The credibility of the certification process depends largely on the strength of the evaluation team (Evans, 1996).

Smart Wood Program - Rainforest Alliance (US)

The Rainforest Alliance established Smart Wood as the first independent forestry certification program in the world in 1990. The program initially focused on tropical forests but is now used to certify forests of all types. Forests have been certified in Java, Honduras, Mexico, Brazil, and Papua New Guinea. The Smart Wood program is similar to the FCP.

Under the program, long-term management data is used to demonstrate that a forest can be classified as a “sustainable source.” Without long-term data but with demonstration that management has a commitment to sustainability, a forest can be classified as “well-managed.”

Smart Wood companies are companies that handle Smart Wood-certified products. Category 1 companies sell products made exclusively from Smart Wood forests, and Category 2 companies sell products made from a mix of certified and non-certified sources. Products from Smart Wood companies carry one of these designations.

Smart Wood certification is based on three broad principles:

- All operations maintain ecosystem functions, including watershed stability and conservation of biological resources.
- Planning and implementation incorporate sustained yield production for all forest products.
- Management activities have a positive impact on local communities.

Smart Wood is developing detailed regional standards with the assistance of local specialists (Evans, 1996).

The Society of American Foresters’ Certified Forester® Program

The Society of American Foresters (SAF), a nonprofit, scientific, and educational organization, established the Certified Forester® (CF) program in 1994. The term *Certified Forester* is registered with the U.S. Patent and Trademark Office and may only be used by individuals who

meet SAF's certification requirements. The CF program is voluntary, nongovernmental, and open to qualified SAF members and nonmembers. A Certified Forester agrees to abide by current CF program requirements and procedures for certification and recertification; to maintain continuing professional development; and to conduct all forestry practices in a responsible, professional manner consistent with state and federal regulations governing environmental quality and forest management practices.

Through the CF program and other activities, SAF advocates wise stewardship in forest resources management. The CF program may supplement or complement state programs to certify, register, or license foresters; however, it is not a substitute for such programs. The CF program provides a consistent, national credential. Due to varying state requirements, not all registered or licensed foresters are routinely eligible to receive CF status.

Certification constitutes recognition by SAF that, to the best of SAF's knowledge, a Certified Forester meets and adheres to certain minimum standards of academic preparation, professional experience, continuing education, and professionalism. No individual is eligible to receive or to maintain Certified Forester status or recertification unless the individual meets and continues to adhere to all requirements for eligibility. Some of the requirements that must be met by all CF applicants include:

- Standards of Professional Practice:

Every CF and applicant for CF status agrees to make every effort to periodically review and follow all applicable state and federal regulations governing environmental quality and, specifically, the stewardship and management of forest resources.

Every CF and applicant for CF status agrees to make every effort to recognize and inform prospective clients or employers of the responsibility to conserve forest resources and to maintain environmental quality in management recommendations.

- Academic Preparation:

Minimum education: Every CF and applicant for CF status must have earned a professional degree from a SAF-accredited or SAF-candidate curriculum, or a substantially equivalent degree from a non-SAF accredited curriculum. Courses that must have been taken include:

Forest ecology and biology: A minimum of one course in each of the three broad subject areas of dendrology, forest ecology, and soils.

Management of forest resources: A minimum of one course in each of the three broad subject areas of forest management, silviculture, and forest protection.

Forest resources policy and administration: A minimum of one course in two of the three broad subject areas of forest policy, forest economics, and business management.

- Professional Experience:

Minimum experience: Five (5) years professional forestry related experience are required for certification. Qualifying experience must be within the 10 years prior to the date of application for certification.

- Continuing Education/Professional Development:

Minimum continuing education: All applicants granted CF status must complete 60 contact hours in continuing forestry education prior to recertification every three years.

A complete Certified Forester® application can be obtained from SAF by calling (301) 897-8720, or sending an E-mail request to cillayp@safnet.org.

Sustainable Forestry Initiative (SFI)SM program of the American Forest & Paper Association

The American Forest & Paper Association (AF&PA) is the national trade association of the forest, pulp, and paper, paperboard, and wood products industry. AF&PA represents approximately 138 member companies and licensees controlling 84% of paper production, 50% of solid wood production, and 90% of the industrial timberland in the United States.

AF&AP member companies, as a condition of membership, must commit to conduct their business in accordance with the principles and objectives of the Sustainable Forestry InitiativeSM program, instituted in October 1994.

The SFISM program is a comprehensive system of principles, objectives and performance measures that integrates the perpetual growing and harvesting of trees with the protection of wildlife, plants, soil and water quality. It is based on the premise that responsible environmental practices and sound business practices can be integrated to the benefit of landowners, shareholders, customers and the people they serve.

Professional foresters, conservationists and scientists developed the SFI program. They were inspired by the concept of sustainability that evolved from the 1987 report of the World Commission on Environment and Development and was subsequently adopted by the 1992 Earth Summit in Rio de Janeiro. The original 1994 SFI Principles and Implementation Guidelines were modified and implemented to become the industry “Standard” in 1999. The standards will continue to be updated periodically to reflect new information concerning forest management and social changes.

SFI State Implementation Committees have formed in 32 states to bring industry representatives together with other stakeholders to support logger-training programs and provide outreach to nonindustrial private landowners and opportunities for public involvement.

In a response to public pressure to broaden the SFI program to include nonmember participation in the SFI, a licensee program has been developed. To date, more than 1.5 million acres have been added to the SFI program through licensee agreements, increasing the total forest acres enrolled in the SFI program to 56.5 million acres.

Member companies and licensees are required to submit annual reports to AF&PA describing progress in implementing the SFI program. Since its inception, member companies of AF&PA have invested more than \$247 million on research related to wildlife, biodiversity, ecosystem management and the environment. By 1998 more than 30,000 independent loggers and foresters completed training in sustainable forestry with an additional 20,000 completing partial training. In addition, SFI participants and professional loggers have distributed information regarding the SFI program to approximately 242,000 landowners across the country since 1994.

The SFI Standard Objectives are presented below.

**SUSTAINABLE FORESTRY:
PRINCIPLES AND IMPLEMENTATION GUIDELINES**

- Sustainable Forestry Principles include the Implementation Guidelines
- **IMPLEMENTATION GUIDELINES FOR SF FOR AF&PA MEMBERS' FORESTS:**
 - OBJECTIVE 1:** Broaden the practice of sustainable forestry by employing an array of scientifically, environmentally, and economically sound practices in the growth, harvest, and use of forests.
 - OBJECTIVE 2:** Promptly reforest harvested areas to ensure long-term forest productivity and conservation of forest resources.
 - OBJECTIVE 3:** Protect the water quality in streams, lakes, and other water bodies by establishing riparian protection measures based on soil type, terrain, vegetation, and other applicable factors, and by using EPA-approved best management practices in all forest management operations.
 - OBJECTIVE 4:** Enhance the quality of wildlife habitat by developing and implementing measures that promote habitat diversity and the conservation of plant and animal populations found in forest communities.
 - OBJECTIVE 5:** Minimize the visual impact by designing harvests to blend into the terrain, by restricting clearcut size and/or by using harvest methods, age classes, and judicious placement of harvest units to promote diversity in forest cover.
 - OBJECTIVE 6:** Manage company lands of ecologic, geologic, or historic significance in a manner that accounts for their special qualities.
 - OBJECTIVE 7:** Contribute to biodiversity by enhancing landscape diversity and providing an array of habitats.
 - OBJECTIVE 8:** Continue to improve forest utilization to help ensure the most efficient use of forest resources.
 - OBJECTIVE 9:** Continue the prudent use of forest chemicals to improve forest health and growth while protecting employees, neighbors, the public, and sensitive areas, including stream courses and adjacent lands.

Summary of Certification Initiatives in the United States

Independent certification programs provide a framework of broad principles and core criteria against which forest management can be assessed. Similar to state forestry programs for best management practice monitoring, forest management under the certification programs is evaluated with field sampling, examinations of documents, and interviews with staff and local stakeholders, evaluation teams are inter-disciplinary and knowledgeable of local conditions, and certification is based on scores for identifiable management actions.

- **IMPLEMENTATION GUIDELINES FOR SUSTAINABLE FORESTRY BY AF&PA MEMBERS IN THE PROCUREMENT OF WOOD AND FIBER FROM LOGGERS AND OTHER LANDOWNERS**

OBJECTIVE 10: Broaden the practice of sustainable forestry by further involving nonindustrial landowners, loggers, consulting foresters and company employees who are active in wood procurement and landowner assistance programs.

- **IMPLEMENTATION GUIDELINES FOR AF&PA MEMBER COMPANIES FOR PUBLIC REPORTING AND INVOLVEMENT IN THE PRACTICE OF SUSTAINABLE FORESTRY**

OBJECTIVE 11: Publicly report AF&PA members' progress in fulfilling their commitment to sustainable forestry.

OBJECTIVE 12: Provide opportunities for the public and the forestry community to participate in the AF&PA membership's commitment to sustainable forestry.

While many certification programs are international in scope and focus, the flexibility to tailor the evaluation to local circumstances is built into the process, so the programs have credibility and can be practically implemented on a local level. Furthermore, the framework of the certification process is a practical forest management tool as the internationally accepted criteria on which evaluations are based provide guidance to forest managers for managing operations for sustainability.

The credibility of the process depends on the expertise of the evaluation team. Persons with local expertise must be used for evaluations in order for the certification process to be placed within a local context, and a local context is absolutely necessary because of the complex inclusion of social, economic, and ecological dimensions in the certification process. This complexity can lead to inconsistencies in evaluations and certifications, but some certification programs, notably the Smart Wood Program, are providing regional, national, and international consistency with the development of regional-specific standards.

A separate approach, the Canadian Standards Association Sustainable Forest Management Project (CSA SFM), is based on developing a preferred future condition that meets society's goals, developing an action plan to move toward the future condition, monitoring progress toward achieving that condition, and correcting one's course of action based on monitoring results. An essential element missing from this approach, and an element that makes the FCP and Smart Wood programs so powerful, is a set of clear criteria that define sustainable forest management. In the CSA SFM approach, this definition is left for local stakeholders to define. This leads to a lack of consistency from operation to operation and certification to certification (Evans, 1996).

Appendix D

Information for Non-Industrial Private Forest (NIPF) Landowners

Non-Industrial Private Forest (NIPF) Management

The approximately 10 million nonindustrial private forest (NIPF) owners in the United States include individuals, partnerships, estates, trusts, clubs, tribes, corporations, and associations (Pennsylvania State University, 2000). NIPF owners control 261 million acres of timberland and 58 percent of the commercial forests in the United States. More than two-thirds of timberland east of the Mississippi River is in NIPF ownership, whereas the majority of timberland in the West is in public ownership. NIPFs protect watersheds, provide wildlife habitat, offer scenic beauty, and supply 49 percent of the timber harvested in the United States (USDA-FS, 1992).

Many NIPF owners are not fully aware of the potential economic value of properly-managed timberland. Others are unaware of how to properly manage their timber resources (Pennsylvania State University, 2000). Proper management might be secondary to avoiding annual property taxes and capital gains taxes for some owners. Other owners who do not plan properly for the inheritance their timberland might lose ownership upon their death, and still others, unaware of either management techniques or the economic value of the land, might decide to convert the land to other uses, such as development or agriculture. Owners who view harvesting of the timber on their land as a one-time capital gain are not aware of the long-term economic and environmental benefits of sustainable timberland management. Andrew Egan of West Virginia University and Stephan Jones of the Alabama Cooperative Extension System studied NIPF owners and timberland management, and found that landowners with knowledge of forests and forestry are more likely to manage their forests in a sustainable manner (Pennsylvania State University, 2000).

Proper implementation of forestry management measures can maintain fish and wildlife habitat, clean water, biological diversity, aesthetics, and a buffer from urban sprawl. NIPF landowners should follow the guidance of the management measures for forestry to protect water quality just as other private and public timberland owners should. Because some of the management measures and BMPs mentioned in the guidance, however, are more relevant to state, federal, and industrial timberland owners, this appendix is provided to focus on certain aspects of planning and managing timberlands that are especially intended to assist NIPF owners in addressing BMP implementation and forest management.

Individual landowners are encouraged to use this guidance to manage and protect water quality on their private forestland. If you have turned directly to this appendix, thinking perhaps that the main sections of the guidance are meant for state agencies and industrial landowners, please take the time to review the rest of the document, especially Section 3. The management measures and practices described in the guidance are applicable to all forest landowners, whether 10 acres or 10,000 acres are being managed. Some of the management measures will be more applicable to some forest management goals than others, but the concepts contained in them are equally relevant to water quality protection in all managed forests where trees are harvested.

Preharvest Planning:

Below are listed some of the more important management practices for achieving the Management Measure for Preharvest Planning. Complete discussions of these and other management practices for preharvest planning can be found in Section 3A. Additional management practices that are particularly applicable to the NIPF landowner follow this listing.

Harvest Planning Practices

- ☐ *Use topographic maps, aerial photographs, soil surveys, geologic maps, and rainfall intensity charts to augment site reconnaissance to lay out and map harvest units. Identify and mark, as needed:*
- ☐ *Consider potential water quality and habitat impacts when selecting the silvicultural system as even-aged (clear-cut, seed tree, or shelterwood) or uneven-aged (group or individual selection). The yarding system, site preparation method, and any pesticides that will be used should also be addressed in preharvest planning. As part of this practice the potential impacts from and extent of roads needed for each silvicultural system should be considered.*
- ☐ *In high-erosion-hazard areas, trained specialists (geologist, soil scientist, geotechnical engineer, wild land hydrologist) should identify sites that have high risk of landslides or that might become unstable after harvest. These specialists can recommend specific practices to reduce the likelihood of erosion hazards and protect water quality.*

Road System Planning Practices

- ☐ *Preplan skid trail and landing locations on stable soils and avoid steep gradients, landslide-prone areas, high-erosion-hazard areas, and poor-drainage areas.*
- ☐ *Identify areas that will require the least modification for use as log landings and use them to reduce the potential for soil disturbance. Use topographic maps and aerial photographs to locate these areas.*
- ☐ *Plot feasible routes and locations on an aerial photograph or topographic map to assist in the final determination of road locations.*
- ☐ *Design roads and skid trails to follow the natural topography and contour, minimizing alteration of natural features.*
- ☐ *In moderately sloping terrain, plan for road grades of less than 10 percent, with an optimal grade of between 3 percent and 5 percent. In steep terrain, short sections of road at steeper grades can be used if the grade is broken at regular intervals. Vary road grades frequently to reduce culvert and road drainage ditch flows, road surface erosion, and concentrated culvert discharges.*

- ☐ *Plan to surface most forest roads, and select a road surface material suitable for the intended road use.*
- ☐ *Lay out roads, skid trails, and harvest units to minimize the number of stream crossings.*
- ☐ *To minimize soil disturbance and road damage, plan to suspend operations when soils are highly saturated. Damage to forested slopes can also be minimized by not operating logging equipment when soils are saturated, during wet weather, or when the ground is thawing.*
- ☐ *Select waterway opening sizes to minimize the risk of washout during the expected life of the structure. Opening size will vary depending on the drainage area of the watershed where the stream-crossing structure is to be placed.*

Additional management practice recommendations for the NIPF landowner

- ☐ *Locate property lines.*

The location of property lines might restrict the use of the best access locations. If significant environmental impact (e.g., erosion, waterbody sedimentation, numerous stream crossing) could be avoided by crossing adjacent property to provide access, consider negotiating or purchasing a right-of-way from the owner of the property.

The USDA Forest Service has produced a document titled *A Landowner's Guide to Building Forest Access Roads* (Wiest, 1998). This document, along with the assistance of a consulting forest engineer, provides support in road planning and location. To receive a copy of this document, contact the USDA Forest Service, Northeastern Area State and Private Forestry, in Radnor, Pennsylvania, (610) 975-4017, or order a copy from the web site at <http://willow.ncfes.umn.edu/accessroads/accessroads.htm>.

- ☐ *Inventory the property.*

Managing timberland requires knowledge of what is on the property. Conduct an inventory to identify features of the land such as streams, steep slopes, eroding or erodible soils, roads and trails, and sensitive wildlife habitats. Aerial photos can be useful for an inventory, but if they are not available for the property, U.S. Geological Survey (USGS) quadrangle map(s) of the area can be used to locate these resources and create a permanent record of them on a map. USGS quadrangle maps show contour lines (steepness of the terrain), existing roads, waterbodies, springs, and buildings. They cost approximately \$5 per map and are available for all of the United States.

- ☐ *Develop a forest management plan.*

Before harvesting operations begin, develop a forest management plan that contains goals, objectives, possible alternatives to harvesting, future planning, and the trade-offs that accompany altering the land. Contact the state department of forestry or cooperative extension service for information on forest harvesting BMPs and their implementation. A logging company is often the primary source of information regarding forestry and nonpoint source pollution control for NIPF

owners, and only by first becoming familiar with the various BMPs can the NIPF landowner be assured that a contractor is choosing and implementing BMPs properly.

The use of a consulting forester or state forester is extremely helpful when developing a forest management plan. The forester can assist with all aspects of forest management and harvest, including the layout of roads and logging decks, BMP implementation, stream protection, and the proper use of chemical. The forester can also educate the NIPF owner about topics such as watershed protection and sustainable forest management.

Streamside Management Areas:

Below are listed some of the more important management practices for achieving the Management Measure for Streamside Management Areas. Complete discussions of these and other management practices for preharvest planning can be found in Section 3B.

- ☐ *Minimize disturbances that would expose the mineral soil of the SMA forest floor. Do not operate skidders or other heavy machinery in the SMA.*
- ☐ *Locate all landings, portable sawmills, and roads outside the SMA.*
- ☐ *Restrict mechanical site preparation in the SMA, and encourage natural revegetation, seeding, and hand planting.*
- ☐ *Limit pesticide and fertilizer usage in the SMA. Establish buffers for pesticide application for all flowing streams.*
- ☐ *Directionally fell trees away from streams to prevent logging slash and organic debris from entering the waterbody. If slash and debris are in the stream as a result of harvesting practices, remove them immediately.*
- ☐ *Apply harvesting restrictions in the SMA to maintain its integrity.*

Road Construction/Reconstruction:

Below are listed some of the more important management practices for achieving the Management Measure for Road Construction and Reconstruction. Complete discussions of these and other management practices for preharvest planning can be found in Section 3C.

Road Surface Construction Practices

- ☐ *Follow the design developed during preharvest planning to minimize erosion by properly timing and limiting ground disturbance operations.*
- ☐ *Properly dispose of organic debris generated during road construction.*
- ☐ *Prevent slash from entering streams and promptly remove slash that accidentally enters streams to prevent problems related to slash accumulation.*

Road Surface Drainage Practices

- ☐ *Install surface drainage controls at intervals that remove storm water from the roadbed before the flow gains enough volume and velocity to erode the surface. Route discharge from drainage structures onto the forest floor so that water will disperse and infiltrate. Methods of road surface drainage include the following:*
- ☐ *Install turnouts, wing ditches, and dips to disperse runoff and reduce the amount of road surface drainage that flows directly into watercourses.*
- ☐ *Install appropriate sediment control structures to trap suspended sediment transported by runoff and prevent its discharge into the aquatic environment.*

Road Slope Stabilization Practices

- ☐ *Use straw bales, straw mulch, grass-seeding, hydromulch, and other erosion control and revegetation techniques to complete the construction project. These methods are used to protect freshly disturbed soils until vegetation is established.*
- ☐ *Revegetate or stabilize disturbed areas, especially at stream crossings.*

Stream Crossing Practices

- ☐ *Construct stream crossings to minimize erosion and sedimentation.*
- ☐ *Install a stream crossing that is appropriate to the situation and conditions.*

Fish Passage Practices

- ☐ *On streams with important spawning areas, avoid construction during egg incubation periods.*
- ☐ *Design and construct stream crossings for fish passage according to site-specific information on stream characteristics and the fish populations in the stream where the passage will be installed.*

Road Management:

Below are listed some of the more important management practices for achieving the Management Measure for Road Management. Complete discussions of these and other management practices for preharvest planning can be found in Section 3D.

Road Maintenance Practices

- ☐ *Blade and reshape the road to conserve existing surface material; to retain the original, crowned, self-draining cross section; and to prevent or remove berms*

(except those designed for slope protection) and other irregularities that retard normal surface runoff.

- ☐ *Maintain road surfaces by mowing, patching, or resurfacing as necessary.*
- ☐ *Clear road inlet and outlet ditches, catch basins, culverts, and road-crossing structures of obstructions as necessary.*

Wet and Winter Road Practices

- ☐ *Before winter, all permanent, seasonal, and temporary roads should be inspected and prepared for the winter months.*

Stream Crossing and Drainage Structure Practices

- ☐ *When temporary stream crossings are no longer needed, and as soon as possible upon completion of operations, remove culverts and log crossings to maintain adequate streamflow.*
- ☐ *During and after logging activities, ensure that all culverts and ditches are open and functional.*
- ☐ *Revegetate disturbed surfaces to provide erosion control and stabilize the road surface and banks.*

Timber Harvesting:

Below are listed some of the more important management practices for achieving the Management Measure for Timber Harvesting. Complete discussions of these and other management practices for preharvest planning can be found in Section 3E. Additional management practices that are particularly applicable to the NIPF landowner follow this listing.

Harvesting Practices

- ☐ *Fell trees away from watercourses whenever possible, keeping logging debris from the channel, except where debris placement is specifically prescribed for fish or wildlife habitat.*
- ☐ *Immediately remove any tree accidentally felled in a waterway.*
- ☐ *Remove slash from the waterbody and place it outside the SMA.*

Practices for Landings

- ☐ *Landings should be no larger than necessary to safely and efficiently store logs and load trucks.*
- ☐ *Upon completion of a harvest, clean up, regrade, and revegetate the landing.*

Ground Skidding Practices

- ☐ *Skid uphill to log landings whenever possible. Skid with ends of logs raised to reduce rutting and gouging.*
- ☐ *Skid perpendicular to the slope (along the contour), and avoid skidding on slopes greater than 40 percent.*

Cable Yarding Practices

- ☐ *Use cabling systems or other systems when ground skidding would expose excess mineral soil and induce erosion and sedimentation.*
- ☐ *Avoid cable yarding in or across watercourses.*

Petroleum Management Practices

- ☐ *Service equipment at a location where any spilled fuel or oil will not reach watercourses, and drain all petroleum products and radiator water into containers.*
- ☐ *Dispose of wastes and containers in accordance with proper waste disposal procedures.*
- ☐ *Take precautions to prevent leakage and spills.*

Additional management practice recommendations for the NIPF landowner

- ☐ *Participate actively in the timber harvest.*

It is important that the NIPF landowner be an active participant in the timber harvest process. Working with the harvesting contractor and state forester, verify that road layout, stream protection, landing locations, skid trail layout, and drainage BMPs all follow the plan developed in the preharvest planning phase. Review the management measures in this guidance prior to developing a plan, note those measures and BMPs particularly relevant to your situation, discuss them with a state forester, and then participate in the harvest to be certain that it is conducted in a manner compatible with the sustainability of your property.

Site Preparation and Forest Regeneration:

Below are listed some of the more important management practices for achieving the Management Measure for Site Preparation and Forest Regeneration. Complete discussions of these and other management practices for preharvest planning can be found in Section 3F.

Site Preparation Practices

- ☐ *Mechanical site preparation should not be conducted on slopes greater than 30 percent.*

- ☐ *Do not conduct mechanical site preparation in SMAs.*

Forest Regeneration Practices

- ☐ *Order seedlings well in advance of planting time to ensure their availability.*
- ☐ *Hand plant highly erodible sites, steep slopes, and lands adjacent to stream channels (SMAs).*

Fire Management:

Below are listed some of the more important management practices for achieving the Management Measure for Fire Management. Complete discussions of these and other management practices for preharvest planning can be found in Section 3G. Additional management practices that are particularly applicable to the NIPF landowner follow this listing.

Prescribed Fire Practices

- ☐ *Carefully plan burning to take into account weather, time of year, and fuel conditions so that these help achieve the desired results and minimize impacts on water quality.*
- ☐ *Intense prescribed fire for site preparation should not be conducted in the SMA.*
- ☐ *Execute the burn with a trained crew and avoid intense burning.*

Additional management practice recommendations for the NIPF landowner

- ☐ *Contact a state forester before any prescribed burning.*

Prescribed burning poses many potential hazards, and the NIPF landowner must be aware of these. Before using fire as a management tool, consult with a professional forester to obtain information on permits, burning times and procedures, equipment, current fire conditions, and safety precautions.

- ☐ *Notify adjacent landowners.*

Before burning, notify adjacent landowners, the local county sheriff, and local fire departments to let them know the date of the burn. A permit might be required for the burn, and it might specify a time period during which the burn must occur. If the burn is not done during the specified period, a new permit must be obtained. Letting all potentially affected parties know that a burn will take place will lessen the likelihood that the fire department will be called to put out the fire. The date of the prescribed burn is always subject to change due to changing weather and fire hazard conditions, and if the date does change, inform the previously notified parties of the new date.

☐ *Hire a professional.*

A landowner who is not proficient in prescribed burning should hire a contractor to perform the burn. Investigate the background and record of any contractor contacted and ask the contractor to provide testimonies of his or her work. Ask the local forestry department, cooperative extension service, or fire department if they have knowledge of the contractor as well. Remember that having a contractor perform the burn does not release the landowner of obligations to notify potentially affected parties, obtain legal information and permits, and ensure that the burn is conducted within the conditions of the permit or recommendations made by the fire or forestry department with respect to time of day, safety precautions, and so forth.

Revegetation of Disturbed Areas:

Below are listed some of the more important management practices for achieving the Management Measure for Revegetation of Disturbed Areas. Complete discussions of these and other management practices for preharvest planning can be found in Section 3H.

- ☐ *Use mixtures of seeds adapted to the site, and avoid the use of exotic species. Species should consist primarily of annuals to allow natural revegetation of native understory plants, and they should have adequate soil-binding properties.*
- ☐ *Seed during optimum periods for establishment, preferably just before fall rains or whenever the optimum period might be for the region.*
- ☐ *Fertilize according to site-specific conditions.*
- ☐ *Inspect all seeded areas for failures, and make necessary repairs and reseed within the planting season.*
- ☐ *During non-growing seasons, apply interim surface stabilization methods to control surface erosion.*

Forest Chemical Management:

Below are listed some of the more important management practices for achieving the Management Measure for Forest Chemical Management. Complete discussions of these and other management practices for preharvest planning can be found in Section 3I. Additional management practices that are particularly applicable to the NIPF landowner follow this listing.

- ☐ *Apply pesticides and fertilizers during favorable atmospheric conditions.*
- ☐ *Apply slow-release fertilizers when possible.*
- ☐ *Apply fertilizers during maximum plant uptake periods to minimize leaching.*
- ☐ *Consider the use of pesticides as only one part of an overall program to control pest problems.*

Additional management practice recommendations for the NIPF landowner

☐ *Contact a state forester.*

Forest landowners who intend to apply chemicals to manage their timber stands should first contact a local forester. The forester will be able to provide information on approved pesticides and fertilizers, application guidelines or requirements, and a list of licensed applicators. It might be possible to hire state foresters to apply chemicals, or they might be willing to act as a foreman on the site to ensure that proper application procedures are followed and hire a licensed contractor to perform the work. Information on such arrangements, for which the landowner pays only part of the total cost, should be available from the state department of forestry or the local cooperative extension service.

Wetlands Forest Management:

Below are listed some of the more important management practices for achieving the Management Measure for Wetlands Forest Management. Complete discussions of these and other management practices for preharvest planning can be found in Section 3J. Additional management practices that are particularly applicable to the NIPF landowner follow this listing.

☐ *Select the harvesting method to minimize soil disturbance and hydrologic impacts on the wetland.*

Additional management practice recommendations for the NIPF landowner

☐ *Contact a state forester or soil scientist to identify forested wetlands.*

Forested wetlands can be difficult to identify. They can occupy very small areas or large areas, can be of any shape, and need not be permanently flooded. Delineation of an area as a wetland requires that three criteria be met:

- Hydrology—a degree of flooding or soil saturation
- Hydrophytic vegetation (vegetation specific to wetlands)
- Hydric soils

These three components can be very site-specific. Differentiating a forested wetland from a non-wetland forest can be difficult. Wetland areas on a property need not be contiguous, and it is possible for a property to have several wetland areas. Some wetlands might be large and easily identified, whereas others might be small and very inconspicuous (Mitsch et al., 1993).

Furthermore, different plant species are adapted to the various conditions that wetlands can occupy, so the absence of wetland plants identified in one wetland area from other areas does not mean that other wetlands do not exist on the property. Because of the complexity of wetland identification, a person licensed in wetland delineation should be consulted if there is any doubt as to whether wetlands exist on a property.

An initial assessment of the existence of wetlands on a property can be done by walking the property and asking some simple questions (Maryland DNR, undated):

- Is the ground moist underfoot?

- Are there springs in the area? (Look at a USGS quadrangle map.)
- Are the tree species considered hydrophytic vegetation? (Use a wetlands tree guide.)
- Are there high-water marks or silt deposits on tree trunks?
- Is water ponded anywhere?
- Do your feet sink into the soil when you walk?
- Dig a hole about a foot deep. Is the soil mostly gray?
- Does the soil in the hole smell like sulphur or rotten eggs?
- Does the hole fill up with water? Does water leak into the hole?
- Is there lush vegetation in some areas and not in others?

To help answer some of the questions, it is useful to have field guides to identify wetland species. Field guides provide descriptions of trees and other wetland vegetation and information on their ranges and habitats.

Contact the local office of the Soil Conservation District to determine whether there are hydric soils on the property. The office will be able to provide a map of the soil series of the property.

Water Quality Protection During Invasive Species Control

Invasive species are gaining a foothold in many parts of the United States, and they can cause extensive damage to a forest. Introduced insects, diseases, and plants can all cause problems for the forest landowner, and the means of control include mechanical, chemical, and biological. Mechanical and chemical control methods, in particular, have the potential to affect water quality. Prior to attempting control of an invasive species, consider using the practices below for the protection of water quality during invasive species control activities. The U.S. Department of Agriculture, the U.S. Forest Service, state forestry agencies, cooperative extension agencies, and local or state universities can provide additional assistance with the identification of invasive species, the problems they cause, and appropriate control methods. Even if you do not believe that you have an invasive species problem, or that your problem is not serious enough to do anything about, it is advised to find out what the invasive species in your area are and what their signs are. Knowing what the problems are can help prevent them or help you identify them before the problem becomes insurmountable and your losses significant.

- ☐ *Consult a state forester before using mechanical control methods.*

The control of invasive species usually requires the implementation of either chemical or mechanical means of control. To ensure that water quality is not compromised when these practices are used, consult with the local county forester before taking any action.

Mechanical control methods used to eradicate an invasive plant, insect, or disease can potentially impair water quality. Some mechanical methods of invasive species removal are cutting, girdling, hand pulling, burning, and grubbing. Some species that can be managed through mechanical control are kudzu (*Pueraria lobata*), tree of heaven (*Ailanthus altissima*), leafy spurge (*Euphorbia esula*), mistletoe (*Phoradendron serotinum*), purple loosestrife (*Lythrum salicaria*), scotch broom (*Cytisus scoparius*), saltcedar (*Tamarix ramosissima*), spruce bark beetle (*Dendroctonus rufipennis*), douglas fir beetle (*Dendroctonus pseudotsugae*), fusiform rust (the fungus *Cronartium fusiforme*), and pine pitch canker (the fungus *Fusarium subglutinans* f. sp. *pini*). The cooperative extension service should be able to provide information on invasive species in your area and appropriate control methods. The following guidelines apply to water quality protection during invasive species control activities:

- Remove invasive species from the SMA only if water quality will not be compromised.
- Do not burn SMAs to eradicate an invasive species.
- Avoid removing infected trees during wet weather periods. This will help reduce erosion potential at the site of removal and on haul roads.

Chemical control of invasive species involves the application of herbicides, pesticides, or fungicides to remove unwanted pests. Review the guidelines for chemical applications in this guidance and provided by your state forestry department before using chemicals for invasive species control.

Additional Resources for the NIPF Landowner:

*Forest*A*Syst*, by Rick Hamilton, extension forestry specialist with the Department of Forestry, North Carolina State University, is a self-assessment guide directed at encouraging forest owners to manage their forests for recreation and aesthetics, wildlife, and timber production, while protecting water quality. The guide discusses steps in developing a forest management plan and strongly recommends the assistance of a professional forester in this process. Major topics are site preparation, natural regeneration, artificial seeding, tree planting, weed control, and fertilization in young and middle-age stands; harvesting the mature forest; managing for wildlife habitat; enhancing the visual appearance of the site; improving recreational opportunities; and using management practices to protect water quality. For additional information on distribution of the publication and support for adapting it to State and local conditions, contact Hamilton at (919) 515-5574 or by e-mail (hamilton@cfr.crf.ncsu.edu) or contact Larry Biles, USDA-CSREES (Cooperative State Research, Education and Extension Service), Washington, DC, at (202) 401-4926.

Landowner's Guide to Building Forest Access Roads, by Richard L. Wiest, is a designed for landowners in the northeastern United States who will use a tractor and ordinary earth moving equipment to build the simplest access roads on their property, or who will contract for these services. Recommendations cover basic planning, construction, drainage, maintenance and closure of such forest roads. Also covers special situations involving water that require individual consideration. Describes geotextiles to be used during temporary road construction. The guide is published by the U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry Division. (1998; 47 p.; \$8.00; order online at <http://www.claitors.com/prf/catalog/001-001-00664-5.html>)

Appendix E

Sample BMP Monitoring Field Sheets

Montana:
Forestry Best Management Practices
Implementation Monitoring

*The 1996 Forestry BMP Audits
Final Report*

Department of Natural Resources and Conservation
Forestry Division
Missoula, Montana

**BMP FIELD AUDITS
SITE INFORMATION**

Site Number: _____ Meets Selection Criteria: _____
High Hazard: _____

Site Name: _____

Owner: _____

Legal Description: _____ County: _____

Primary Drainage: _____ Month/Year Harvested: _____

Stream Within 200 Ft.? Y / N Name: _____ Bankfull Width: _____

Unit Size: _____ Volume Removed: _____

Road Construction: _____ Length: _____

Road Reconstruction: _____ Length: _____

Slash Disposal Complete: _____ Method: _____

Logging Method: _____

Slope: 0-5% ____; 5-20% ____; 20-40% ____; 40%+ ____

Parent Material: _____

Soil Erodibility: High ____ Medium ____ Low ____

Harvest in Riparian: Y / N

Stream Class: _____

Comments: _____

RATING GUIDE

APPLICATION

- 5--OPERATION EXCEEDS REQUIREMENTS OF BMP
- 4--OPERATION MEETS REQUIREMENTS OF BMP
- 3--MINOR DEPARTURE FROM BMP
- 2--MAJOR DEPARTURE FROM BMP
- 1--GROSS NEGLECT OF BMP

EFFECTIVENESS

- 5--IMPROVED PROTECTION OF SOIL AND WATER RESOURCES OVER PRE-PROJECT CONDITION
- 4--ADEQUATE PROTECTION OF SOIL AND WATER RESOURCES
- 3--MINOR AND TEMPORARY IMPACTS ON SOIL & WATER RESOURCES
- 2--MAJOR AND TEMPORARY OR MINOR AND PROLONGED IMPACTS ON SOIL AND WATER RESOURCES.
- 1--MAJOR AND PROLONGED IMPACTS ON SOIL AND WATER RESOURCES.

DEFINITIONS (BY EXAMPLE):

ADEQUATE--SMALL AMOUNT OF MATERIAL ERODED; MATERIAL DOES NOT REACH DRAWS, CHANNELS, OR FLOODPLAIN.
MINOR--EROSION AND DELIVERY OF MATERIAL TO DRAWS BUT NOT STREAM.
MAJOR--EROSION AND SUBSEQUENT DELIVERY OF SEDIMENT TO STREAM OR ANNUAL FLOODPLAIN.
TEMPORARY--IMPACTS LASTING ONE YEAR OR LESS; NO MORE THAN ONE RUNOFF SEASON.
PROLONGED--IMPACTS LASTING MORE THAN ONE YEAR.

FIELD AUDIT

Date: _____

Team Leader/Recorder: _____

Team Members: _____

Observers Present: _____

NR--NOT REVIEWED

NA--NOT APPLICABLE

MONTANA FOREST PRACTICES REVIEW WORKSHEET

BMPs Applicable to:

- + New Road Construction
- * Existing Roads
- Reconstruction

| RECOMMENDED BEST MANAGEMENT PRACTICES | APPLICABLE TO SITE (Y/N) | | | COMMENTS |
|---|--------------------------|--|---------------|----------|
| | APPLICATION | | | |
| | | | EFFECTIVENESS | |
| SECTION I--ROADS | | | | |
| <u>ROAD PLANNING & LOCATION</u> | | | | |
| <u>SECTION I.A.</u> | | | | |
| ▸+ 1a. MINIMIZE NUMBER OF ROADS NECESSARY. | | | | |
| * 1b. USE EXISTING ROADS UNLESS AGGRAVATE EROSION. | | | | |
| + 3. AVOID LONG, SUSTAINED, STEEP ROAD GRADES. | | | | |
| + 4. LOCATIONS AVOID HIGH HAZARD SITES (I.E., WET AREAS AND UNSTABLE SLOPES). | | | | |
| + 5. ADEQUATE SMZ BETWEEN ROAD AND STREAM CHANNELS WHERE ROADS ARE LOCATED ALONG STREAMS. | | | | |
| + 6a. MINIMIZE NUMBER OF STREAM CROSSINGS. NUMBER _____. | | | | |
| + 6b. CHOOSE STABLE STREAM CROSSING SITES. | | | | |
| <u>ROAD DESIGN</u> | | | | |
| <u>SECTION I.B.</u> | | | | |
| ▸+ 2. DESIGN ROADS TO MINIMUM STANDARD NECESSARY TO ACCOMMODATE ANTICIPATED USES. | | | | |
| + 4. VARY ROAD GRADE TO REDUCE CONCENTRATED DRAINAGE. | | | | |
| +▸ 5. PROPER SIZING FOR CROSSING STRUCTURES. | | | | |
| <u>DRAINAGE FROM ROAD SURFACE</u> | | | | |
| <u>SECTION I.C.</u> | | | | |
| +▸* 1. PROVIDE ADEQUATE ROAD SURFACE DRAINAGE FOR ALL ROADS. | | | | |

I.D. _____ + New Road Construction; * Existing Roads; ► Reconstruction

| RECOMMENDED BEST MANAGEMENT PRACTICES | | APPLICABLE TO SITE (Y/N) | | | COMMENTS | |
|---|-----|--|--|--|----------|--|
| | | APPLICATION EFFECTIVENESS | | | | |
| +► | 2. | SKEW DITCH RELIEF CULVERTS. | | | | |
| +►* | 4. | PROVIDE ENERGY DISSIPATORS AT DRAINAGE STRUCTURE OUTLETS WHERE NEEDED. | | | | |
| +►* | 6. | ROUTE ROAD DRAINAGE THROUGH ADEQUATE FILTRATION ZONES BEFORE ENTERING A STREAM. | | | | |
| <u>CONSTRUCTION/RECONSTRUCTION SECTION I.D.</u> | | | | | | |
| +► | 2. | STABILIZE ERODIBLE SOILS (I.E., SEEDING, BENCHING, MULCHING). | | | | |
| +► | 3. | SLASH FILTER WINDROWS INSTALLED. | | | | |
| +► | 5. | CUT AND FILL SLOPES AT STABLE ANGLES. SLOPE RATIO: _____. | | | | |
| +► | 6. | AVOID INCORPORATING WOODY DEBRIS IN ROAD FILL. | | | | |
| +► | 8. | EXCESS MATERIALS (WASTE) PLACED IN LOCATIONS THAT AVOID ENTERING STREAM. | | | | |
| +► | 9. | SEDIMENT FROM BORROW PITS AND GRAVEL PITS MINIMIZED. | | | | |
| ► | 10. | RECONSTRUCT ONLY TO THE EXTENT NECESSARY TO PROVIDE ADEQUATE DRAINAGE AND SAFETY. | | | | |
| <u>ROAD MAINTENANCE SECTION I.E.</u> | | | | | | |
| +►* | 1. | GRADE ROADS IF NECESSARY TO MAINTAIN DRAINAGE. | | | | |
| +►* | 2. | MAINTAIN EROSION CONTROL FEATURES (DIPS, DITCHES AND CULVERTS FUNCTIONAL). | | | | |
| * | 3. | AVOID CUTTING THE TOE OF CUT SLOPES. | | | | |
| +►* | 6. | AVOID USE OF ROADS DURING WET PERIODS AND SPRING BREAKUP. | | | | |
| +►* | 8. | ABANDONED ROADS IN CONDITION TO PROVIDE ADEQUATE DRAINAGE WITHOUT FURTHER MAINTENANCE. | | | | |

I.D. _____ + New Road Construction; * Existing Roads; ► Reconstruction

RECOMMENDED BEST
MANAGEMENT PRACTICES

APPLICABLE TO SITE (Y/N)

APPLICATION
EFFECTIVENESS

COMMENTS

SECTION II--TIMBER HARVESTING

HARVEST DESIGN
SECTION II.A.

2. SUITABLE LOGGING SYSTEM FOR TOPOGRAPHY, SOIL TYPE AND SEASON OF OPERATION.
5. DESIGN AND LOCATE SKID TRAILS TO AVOID CONCENTRATING RUNOFF.
6. SUITABLE LOCATION, SIZE, AND NUMBER OF LANDINGS.

OTHER HARVESTING ACTIVITIES
SECTION II.C.

- 1a. SKIDDING OPERATION MINIMIZES SOIL COMPACTION AND DISPLACEMENT.
- 1b. AVOID TRACTOR SKIDDING ON UNSTABLE SLOPES AND SLOPES THAT EXCEED 40% UNLESS NOT CAUSING EXCESSIVE EROSION.
- 2a. ADEQUATE DRAINAGE FOR TEMPORARY ROADS, SKID TRAILS AND FIRE LINES.
- 2b. ADEQUATE DRAINAGE FOR LANDINGS.

SLASH TREATMENT AND SITE PREPARATION
SECTION II.D.

2. BRUSH BLADES USED ON DOZERS.
4. SCARIFY ONLY TO THE EXTENT NECESSARY TO MEET REFORESTATION OBJECTIVE.
5. ACTIVITIES LIMITED TO FROZEN OR DRY CONDITIONS TO MINIMIZE SOIL COMPACTION AND DISPLACEMENT.
6. EQUIPMENT OPERATIONS ON SUITABLE SLOPES ONLY.
9. LIMIT WATER QUALITY IMPACT OF PRESCRIBED FIRE.

I.D. _____ + New Road Construction; * Existing Roads; ► Reconstruction

| RECOMMENDED BEST MANAGEMENT PRACTICES | APPLICABLE TO SITE (Y/N) | | | COMMENTS |
|--|--------------------------|---------------|--|----------|
| | APPLICATION | EFFECTIVENESS | | |
| SECTION III--STREAM CROSSINGS | | | | |
| <u>LEGAL REQUIREMENTS</u> <u>SECTION III.A.</u> | | | | |
| ►+ 1. PROPER PERMITS FOR STREAM CROSSINGS. | | | | |
| <u>DESIGN CONSIDERATIONS</u> <u>SECTION III.B.</u> | | | | |
| ►+ 1a. CROSS STREAMS AT RIGHT ANGLES, IF PRACTICAL. | | | | |
| ►+ 1b. DIRECT ROAD DRAINAGE AWAY FROM STREAM CROSSING SITE. | | | | |
| ►+ 2. AVOID UNIMPROVED STREAM CROSSINGS. | | | | |
| <u>INSTALLATION OF STREAM CROSSINGS</u> <u>SECTION III.C.</u> | | | | |
| ►+ 1. MINIMIZE STREAM CHANNEL DISTURBANCE. | | | | |
| ►+ 2. CULVERTS CONFORM TO NATURAL STREAMBED AND SLOPE. | | | | |
| ►+ 3. PREVENT EROSION OF CULVERT AND BRIDGE FILLS (I.E., ARMOR INLET AND OUTLET. | | | | |
| ►+ 5. MINIMUM COVER FOR CULVERTS PROVIDED. | | | | |
| SECTION V--HAZARDOUS SUBSTANCES | | | | |
| <u>GENERAL</u> <u>SECTION V.A.</u> | | | | |
| 2. ADEQUATE STORAGE AND DISPOSAL FOR FUEL, SHOP DEBRIS, AND WASTE OIL. | | | | |
| WERE ANY CWE ASSESSMENTS OR WATERSHED ANALYSIS INCLUDED IN THE TIMBER HARVEST PLANNING? | RESPONSE: | | | |
| IF YES, WHAT TYPE AND LEVEL OF ANALYSIS WAS CARRIED OUT (I.E., MONITORING, SCREENING, CWE INDICES, INTERDISCIPLINARY TEAMS, ASSESSMENTS OF CHANGING GEOMORPHIC PROCESSES, A COMBINATION OF TWO OR MORE.) | | | | |

I.D. _____ + New Road Construction; * Existing Roads; ► Reconstruction

STREAMSIDE MANAGEMENT ZONE SITE INFORMATION

ARE SMZ RULES APPLICABLE? (EFF. 3/15/93) Y / N

WERE ANY PRE-APPROVED ALTERNATIVE PRACTICES UTILIZED?
(* DENOTES PRACTICES THAT APPLY.)

Y / N (LIST APPLIED PRACTICES)

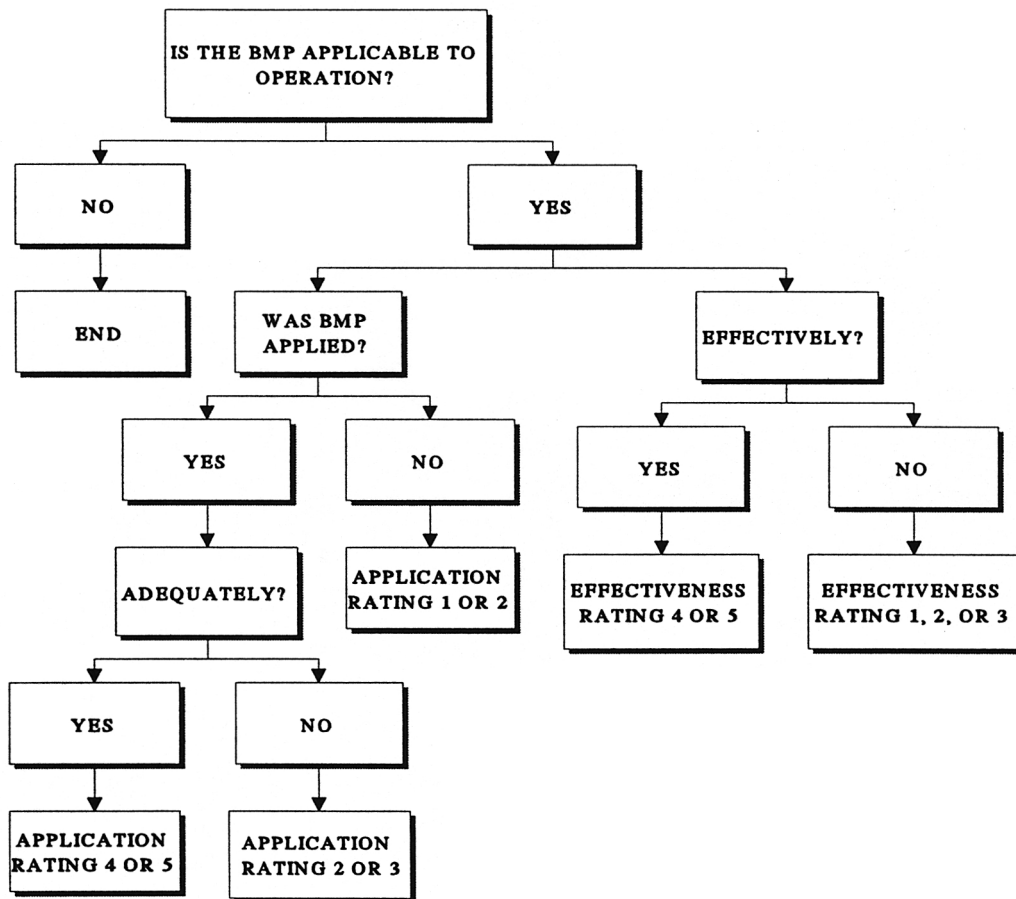
WERE ANY DNRC-APPROVED SITE-SPECIFIC ALTERNATIVE PRACTICES IMPLEMENTED IN THE HARVEST ACTIVITIES?
(** DENOTES PRACTICES THAT APPLY.)

Y / N (LIST APPLIED PRACTICES)

| RECOMMENDED BEST MANAGEMENT PRACTICES | APPLICABLE TO SITE (Y/N) | | | COMMENTS |
|--|--------------------------|--|--|----------|
| | APPLICATION | | | |
| | EFFECTIVENESS | | | |
| | | | | |
| 1. ADEQUATE SMZ WIDTH MAINTAINED AND PROPERLY MARKED? AVG. WIDTH ____. | | | | |
| 2. EXCLUSION OF BROADCAST BURNING IN SMZ.** | | | | |
| 3. SMZ RETENTION TREE REQUIREMENTS MET. (# OF TREES, REPRESENTATIVE OF PRE-HARVEST STAND, FAVOR BANK-EDGE AND LEANING TREES, SHRUBS AND SUBMERCHTABLE) ** | | | | |
| 4. EXCLUSION OF EQUIPMENT OPERATION IN SMZ EXCEPT ON ESTABLISHED ROADS.* | | | | |
| 5. EXCLUDE CONSTRUCTION OF ROADS IN THE SMZ EXCEPT WHEN NECESSARY TO CROSS A STREAM OR WETLAND.** | | | | |
| 6. EXCLUSION OF ROAD FILL MATERIAL DEPOSITED IN SMZ EXCEPT AS NEEDED TO CONSTRUCT CROSSINGS. | | | | |
| 7. EXCLUSION OF SIDE-CASTING OF ROAD MATERIAL INTO A STREAM, LAKE, WETLAND OR OTHER BODY OF WATER DURING ROAD MAINTENANCE. | | | | |
| 8. EXCLUSION OF SLASH IN STREAMS, LAKES OR OTHER BODIES OF WATER.** | | | | |
| 9. EXCLUDE THE HANDLING, STORAGE, APPLICATION OR DISPOSAL OF HAZARDOUS OR TOXIC MATERIALS IN THE SMZ IN A MANNER THAT POLLUTES OR CAUSES DAMAGE OR INJURY. | | | | |

ADDITIONAL COMMENTS:

**RATIONALE FOR THE RATING SYSTEM
POST HARVEST EVALUATION**



U.S. Department of Agriculture
Forest Service

*Investigating Water Quality in the Pacific Southwest Region:
Best Management Practices Evaluation Program*

Pacific Southwest Region
1992

Best Management Practices Evaluation

UTM Coordinates Zone __ __
 Easting _____
 Northing _____

Form T01: Streamside Management Zones (BMP 1.8, 1.19, 1.22)

ID#: _____

Selection Code: _____

Reviewer(s) _____ Title(s) _____ Date _____ Forest _____ District _____ T _____ R _____ S _____

Project _____ Unit # _____ Year Logging Occurred _____ Rock Type _____ Stream _____

SMZ Rx: _____ Activity Status _____ NFS Watershed _____

IMPLEMENTATION

Rating

- 1) Was SMZ clearly identified on the ground? _____
- 2) SMZ width is as specified? _____
- 3) Treatment of SMZ is as prescribed? _____
- 4) Mechanized equipment restricted from SMZ during
 timber harvest except at approved crossings? _____
- 5) Logging slash in SMZ treated by means other than mechanized equipment? _____

1 = Exceeds contract/project requirements
 2 = Meets contract/project requirements
 3 = Minor departure from contract/project requirements
 4 = Major departure from contract/project requirements
 Rate as NA if criteria not applicable at this site

If any rating is "3" or "4", complete the following:

Problem occurred in which phase(s) of the project: ☐ Site Evaluation ☐ Plan Prescription ☐ EA ☐ Contract ☐ Layout ☐ Administration ☐ Post Sale

Describe deficiencies and corrective actions:

EFFECTIVENESS

- | | | | |
|--------------------------------------|---|--|---|
| 1) Groundcover (Objective: _____%*) | <input type="checkbox"/> No disturbance or meets or exceeds objective | <input type="checkbox"/> Groundcover \geq 80% of objective | <input type="checkbox"/> Groundcover < 80% of objective |
| 2) Canopy cover (Objective: _____%*) | <input type="checkbox"/> No disturbance or meets or exceeds objective | <input type="checkbox"/> Canopy cover \geq 90% of objective | <input type="checkbox"/> Canopy cover < 90% of objective |
| 3) Disturbance to streambanks | <input type="checkbox"/> None evident | <input type="checkbox"/> Disturbance is less than 5% of channel length | <input type="checkbox"/> Activities have disturbed more than 5% of channel length |
| 4) Sediment to channel | <input type="checkbox"/> Evidence of sediment movement to SMZ | <input type="checkbox"/> Erosion/sediment movement into SMZ but no sediment to channel | <input type="checkbox"/> Evidence that sediment has entered channel |

*Use project, LMP or Forest Objective. If prescription is "no disturbance", enter "100".

If poor effectiveness is evident, comment on:

(1) Possible causes (e.g., site sensitivity, inadequate BMP prescription, major storm event, etc.):

(2) The degree and duration of effects on beneficial uses of water:

Continued on reverse? ☐

Best Management Practices Evaluation

UTM Coordinates Zone _ _
Easting _ _ _ _ _
Northing _ _ _ _ _

Form T02: Skid Trails (BMP 1.10 & 1.17)

ID#: _____
Selection Code: _____

Reviewer(s) _____ Title(s) _____ Date _____ Forest _____ District _____
Project _____ Unit # _____ Year Logging Occurred _____ T _____ R _____ S _____
Rock Type _____ NFS Watershed _____

IMPLEMENTATION

Skid Trails comply with FSH standards, and any special EA conditions as they relate to:

Rating

- a) Location _____
b) Drainage and Erosion Control _____
c) Width _____
d) Drainage Crossings _____
f) Endlining (if req. by TSC C.6.422) _____

1 = Exceeds contract/project requirements
2 = Meets contract/project requirements
3 = Minor departure from contract/project requirements
4 = Major departure from contract/project requirements
Rate as NA if criteria not applicable at this site

If any Implementation Rating is "3" or "4", complete the following:

Problem occurred in which phase(s) of the project: ☐ Site Evaluation ☐ Plan Prescription ☐ EA/EIS ☐ Contract ☐ Layout ☐ Administration

Describe deficiencies and corrective actions:

EFFECTIVENESS

- | | | | |
|----------------------------------|--|--|---|
| 1) Ground Disturbance | <input type="checkbox"/> Skid trails disturb less than 10% of unit | <input type="checkbox"/> Skid trails disturb > 10% but < 15% of unit | <input type="checkbox"/> Skid trails disturb > 15% of unit |
| 2) Erosion on skid trail surface | <input type="checkbox"/> Little or no evidence of rills | <input type="checkbox"/> Rills present, but occur on < 20% of skid trail surfaces | <input type="checkbox"/> > 20% of surface has rills, or rills present that are > 2" deep and > 10' long |
| 3) Rutting | <input type="checkbox"/> Little or no evidence of rutting | <input type="checkbox"/> Some rutting present, but < 10% of area has ruts > 2" deep | <input type="checkbox"/> > 10% of surface length has ruts > 2" deep |
| 4) Waterbars | | | |
| a) Diversion of runoff | <input type="checkbox"/> < 10% of waterbars fail to divert flow off of skid trail | <input type="checkbox"/> > 10% but < 20% of waterbars fail to divert flow off skid trails | <input type="checkbox"/> > 20% of waterbars fail to divert flow from skid trail |
| b) Sediment below outlet | <input type="checkbox"/> Sediment deposition absent or does not extend beyond outlet control | <input type="checkbox"/> Sediment deposition evident but does not extend > 20' below waterbar outlet | <input type="checkbox"/> Sediment deposition extends > 20' below waterbar outlet |
| c) Erosion below outlet | <input type="checkbox"/> No evidence of rills or gullies | <input type="checkbox"/> Rills present, but < 20' long or occur on < 20% of waterbar outlets | <input type="checkbox"/> Rills > 20' long or occur on > 20% of waterbar outlets |
| d) Sediment to channel | <input type="checkbox"/> No evidence of transport to SMZ | <input type="checkbox"/> Sediment deposited in SMZ but not in channel | <input type="checkbox"/> Evidence of sediment transport to or deposition in channel |

over

Form T02: Skid Trails (Page 2)
(BMP 1.10 & 1.17)

EFFECTIVENESS (*ccntinued*)

FOR SITES WITH STREAM CROSSINGS:

- 5) Sediment to Channel: stream crossing rilling
- | | | |
|---|---|--|
| <input type="checkbox"/> Rills may be evident, but are infrequent appear stable, with no evident sediment delivery to channel | <input type="checkbox"/> Rills present, but average less than 1 per 5' lineal, rills not enlarging. Minimal evidence of deposition in channel. No gullies | <input type="checkbox"/> Numerous rills present (>1 per 5" lineal) apparantly active or enlarging, evidence of delivery to channel, or gullies present |
|---|---|--|

If poor effectiveness is evident, comment on:

(1) Possible causes (*e.g., site sensitivity, inadequate BMP prescription, major storm event, etc.*):

(2) The degree and duration of effects on beneficial uses of water:

Best Management Practices Evaluation

UTM Coordinates Zone __ __
 Easting __ __ __ __ __ __
 Northing __ __ __ __ __ __

Form T04: Landings (BMP 1.12, 1.16)

ID#: _____
 Selection Code: _____

Reviewer(s) _____ Title(s) _____ Date _____ Forest _____ District _____ T _____ R _____ Sec _____
 Project _____ Unit # _____ Year Logging Occurred: _____ Rock Type _____ NFS Watershed _____
 Special measures required on this landing: ☐ Vegetative Soil Stabilization (C6.601) ☐ Special Erosion Control (C6.602) ☐ Soil Scarification (C6.603)

IMPLEMENTATION

Was the landing ripped? ☐ yes ☐ no

Landing placement and erosion control treatment complies with FSH 2409.23 standards, and any special EA conditions as they relate to:

- | | |
|-------------------|-------|
| a) Location | _____ |
| b) Drainage | _____ |
| c) Size | _____ |
| d) Rehab | _____ |

Rating

1 = Exceeds contract/project requirements
 2 = Meets contract/project requirements
 3 = Minor departure from contract/project requirements
 4 = Major departure from contract/project requirements
 Rate as NA if criteria not applicable at this site

If any rating is "3" or "4", complete the following:

Problem occurred in which phase(s) of the project: ☐ Site Evaluation ☐ Plan Prescription ☐ EA ☐ Contract ☐ Layout ☐ Administration

Describe deficiencies and corrective actions:

EFFECTIVENESS

1) Landing Surface Erosion

- | | | | |
|------------|--|--|--|
| a) Rilling | <input type="checkbox"/> Less than 1 rill per 100' of transect | <input type="checkbox"/> Some rilling but less than 1 rill per 20' of transect | <input type="checkbox"/> Rilling present that exceeds 1 rill per 20' of transect, or gully present |
|------------|--|--|--|

2) Drainage (Describe type of drainage control used: out sloping, waterbars, etc.)

- | | | | |
|------------------------------|---|---|---|
| a) Drainage runoff structure | <input type="checkbox"/> No evidence of concentrated flow | <input type="checkbox"/> Evidence of rills or gullies from concentrated flow, but do not extend > 20' below edge of landing | <input type="checkbox"/> Evidence of rills or gullies resulting from concentrated flow which extend > 20' below edge of landing |
|------------------------------|---|---|---|

3) Landing fill slopes (Write NA if there are no fill slopes on the landing you are evaluating)

- | | | | |
|-----------------------------|---|---|--|
| a) Rilling | <input type="checkbox"/> No evidence of rills | <input type="checkbox"/> Rills present but do not extend > slope length below toe of fill | <input type="checkbox"/> Rills present and extend > slope length below toe of fill |
| b) Sediment below fillslope | <input type="checkbox"/> Little or none | <input type="checkbox"/> Some deposition, but none > slope length below toe of fill | <input type="checkbox"/> Heavy deposition & extends beyond toe of fill |

4) Sediment

- | | | | |
|--------------------------------|---|--|---|
| a) Sediment to nearest channel | <input type="checkbox"/> No evidence of transport to SMZ | <input type="checkbox"/> Sediment deposition in SMZ but not channel | <input type="checkbox"/> Evidence of sediment transport to or deposition in channel |
| b) Slope failures | <input type="checkbox"/> < 1 cubic yard of material moved | <input type="checkbox"/> ≥ 1 cubic yard of material moved but does not enter channel | <input type="checkbox"/> ≥ 1 cubic yard of material moved, some material enters channel |

If poor effectiveness is evident, comment on:

(1) Possible causes (e.g., site sensitivity, inadequate BMP prescription, major storm event, etc.):

(2) The degree and duration of effects on beneficial uses of water:

Continued on reverse? ☐

Best Management Practices Evaluation

UTM Coordinates Zone _ _
Easting _ _ _ _ _
Northing _ _ _ _ _

Form E08: Road Surface, Drainage and Slope Protection (BMP 2.2, 2.4, 2.5, 2.7, 2.10, 2.23)

ID#: _____

Selection Code: _____

Reviewer(s) _____ Title(s) _____ Date _____ Forest _____ District _____ T _____ R _____ S _____

Project _____ Road # _____ Year Construction Completed _____ Last Maintenance _____

Project is: ☐ Construction ☐ Reconstruction ☐ Maintenance ☐ Other (describe) _____ NFS Watershed _____

IMPLEMENTATION

Rating

For construction or reconstruction projects:

- 1) Design objectives developed that address water quality issues identified by ID or review team _____
- 2) Design meets objectives _____
- 3) Construction/Reconstruction contract requirements met for:
 - a) Surfacing _____
 - b) Drainage _____
 - c) Slope stabilization _____
 - d) Slash disposal _____

1 = Exceeds contract/project requirements
2 = Meets contract/project requirements
3 = Minor departure from contract/project requirements
4 = Major departure from contract/project requirements
Rate as NA if criteria not applicable at this site

For maintenance projects:

- 1) Check appropriate means of maintenance accomplishment: ☐ Timber sale contract
☐ Force account
☐ Maintenance contract
☐ Other (_____)
- 2) Maintenance specifications were met for:
 - a) Surface blading/repair/treatment _____
 - b) Drainage structure repair/treatment _____
 - c) Slope treatment/sidecast _____

If any rating is "3" or "4", complete the following:

Problem occurred in which phase(s) of the project: ☐ Location ☐ Design ☐ EA ☐ Contract ☐ Construction ☐ Maintenance

Describe deficiencies and corrective actions:

over

Form E08: Road Surface, Drainage and Slope Protection (page 2)

(BMP 2.2, 4, 5, 7, 10, 23)

Evaluation starting point was adjacent to a:

☐ Perennial

☐ Intermittent

☐ Ephemeral

stream

EFFECTIVENESS

1) Road surface

a) Rilling

☐ Little or no evidence

☐ Some present, but occurs on <10% of road length, or where present do not leave road surface

☐ >10% of surface length has rills 2" deep and 20' in length which continue off road surface

2) Fill slopes

a) Rilling

☐ No evidence of rills

☐ Rills present but do not extend > slope length below toe

☐ Rills present and extend > slope length below toe

b) Sediment to nearest channel

☐ No evidence of transport to SMZ

☐ Sediment deposition in SMZ but not channel

☐ Sediment from fill slope enters channel

c) Slope failures

☐ Less than 5 cubic yards of material moved

☐ ≥ 5 cubic yards of material moved, material does not enter channel

☐ Slide material enters channel

3) Cut slope failure/inside ditch

☐ Less than 5 cubic yards of material moved and material does not enter channel

☐ ≥ 5 cubic yards of material moved but does not enter drainage way to channel

☐ ≥ 5 cubic yards of material moved. > 2 cubic yards of material transported to channel

4) Cross drains (Note: apply E09 evaluation at streamcrossings. Use these criteria at cross drain pipes, dips, waterbars or other cross drain structures if they occur along transect.)

a) Scour at outlet

☐ No evidence of scour

☐ Scour evident, but does not extend >20' below outlet

☐ Scour and/or sediment extends to stream channel

b) Plugging

☐ No evidence of sediment or debris restricting flow

☐ Sediment and/or debris is accumulating, but ≤ 30% of inlet or outlet is blocked

☐ Sediment and/or debris is blocking > 30% of inlet or outlet

If poor effectiveness is evident, comment on:

(1) Possible causes (e.g., site sensitivity, inadequate BMP prescription, major storm event, etc.):

(2) The degree and duration of effects on beneficial uses of water:

Best Management Practices Evaluation

UTM Coordinates Zone _ _
Easting _ _ _ _ _
Northing _ _ _ _ _

Form E09: Stream Crossings (BMP 2.1, 2.4, 2.5, 2.7, 2.10, 2.23)

ID#: _____

Selection Code: _____

Reviewer(s) _____ Date _____ Forest _____ District _____ T _____ R _____ S _____ NFS Watershed _____

Project _____ Road # _____ Year Construction Completed _____ Last Maintenance _____

Project is: ☐ Construction ☐ Reconstruction ☐ Maintenance ☐ Other (describe) _____

IMPLEMENTATION

Rating

For construction or reconstruction projects:

1) Design objectives developed that address water quality issues identified by ID or review team _____

Crossing structure design-flow return period _____

2) Design meets objectives _____

3) Construction/Reconstruction contract requirements met for:

a) Slash disposal _____

b) Structure type _____

c) Road surface _____

d) Structure placement (culvert, bridge, etc.) _____

e) Slope stabilization _____

f) Drainage _____

1 = Exceeds contract/project requirements

2 = Meets contract/project requirements

3 = Minor departure from contract/project requirements

4 = Major departure from contract/project requirements

Rate as NA if criteria not applicable at this site

For maintenance projects:

- 1) Check appropriate means of maintenance accomplishment: ☐ Timber sale contract
☐ Force account
☐ Maintenance contract
☐ Other (_____)

2) Maintenance specifications were met for:

a) Drainage structure repair/treatment _____

b) Slope treatment/sidecast _____

c) Surface treatment _____

If any rating is "3" or "4", complete the following:

Problem occurred in which phase(s) of the project: ☐ Location ☐ Design ☐ EA ☐ Contract ☐ Construction ☐ Maintenance

Describe deficiencies and corrective actions:

over

Form E09: Stream Crossings (page 2)

Stream crossing is at a: ☐ Perennial ☐ Intermittent ☐ Ephemeral stream

EFFECTIVENESS

1) Fill Slopes

- | | | | |
|---------------------|---|--|---|
| a) Vegetative cover | <input type="checkbox"/> Vigorous dense cover, or fillslope of stable material | <input type="checkbox"/> Less than full cover, but > 50% of fillslope has effective cover or is stable material | <input type="checkbox"/> < 50% of fillslope has effective cover or is stable material |
| b) Rilling | <input type="checkbox"/> Rills may be evident, but are infrequent, stable, with no evident sediment delivery to channel | <input type="checkbox"/> Rills present, but less than 1 per lineal 5'. Rills not enlarging. Minimal evidence of deposition in channel, and no gullies. | <input type="checkbox"/> Numerous rills present (>1 rill per lineal 5'), apparently active or enlarging, evidence of delivery to channel, or gullies present. |
| c) Cracks | <input type="checkbox"/> None evident | <input type="checkbox"/> Cracks present, but appear to be stabilized | <input type="checkbox"/> Present, widening, threatening integrity of fill |
| d) Slope failures | <input type="checkbox"/> Less than 1 cubic yard of material | <input type="checkbox"/> ≥ 1 cubic yard of material moved but does not enter stream | <input type="checkbox"/> ≥ 1 cubic yard of material moved, material enters stream |

2) Road surface

- | | | | |
|---------------------|--|---|--|
| a) Rilling | <input type="checkbox"/> Little or no evidence of rills | <input type="checkbox"/> Some present, but occurs on < 10% of road surface area, or where present do not leave road surface | <input type="checkbox"/> > 10% of surface has rills 2" deep and 20" in length which continue off road surface onto crossing fill |
| b) Puddling | <input type="checkbox"/> No evidence of ponded water | <input type="checkbox"/> Some ponding, but does not appear to threaten integrity of fill | <input type="checkbox"/> Ponding present that is causing fill subsidence or otherwise threatening integrity of fill |
| c) Drainage ditches | <input type="checkbox"/> Stable drainage with little or no sediment delivery to stream | <input type="checkbox"/> Less than 2 cubic yards erosion but configuration is stable or stabilizing | <input type="checkbox"/> More than 2 cubic yards of sediment delivery to stream and configuration is unstable/degrading |

3) Culvert

- | | | | |
|------------------------|--|---|---|
| a) Scour at outlet | <input type="checkbox"/> No evidence of scour | <input type="checkbox"/> Scour evident, but extends less than 2 channel widths below outlet; and no undercutting of crossing fill | <input type="checkbox"/> Scour evident that extends more than 2 channel widths below outlet, or scour is undercutting crossing fill |
| b) Diversion potential | <input type="checkbox"/> Crossing is configured to pass flows without diversion if culvert fails | | <input type="checkbox"/> If culvert fails, flow will be diverted out of channel and down roadway |
| c) Plugging | <input type="checkbox"/> No evidence of sediment or debris restricting flow through pipe | <input type="checkbox"/> Sediment and/or debris is accumulating, but $\leq 30\%$ of inlet or outlet is blocked | <input type="checkbox"/> Sediment and/or debris is blocking >30% of inlet or outlet |
| d) Piping | <input type="checkbox"/> No evidence of flow beneath or around culvert | | <input type="checkbox"/> $\geq 10\%$ of the flow passes beneath or around culvert, or substantial piping erosion evident |

If poor effectiveness is evident, comment on:

(1) Possible causes (e.g., site sensitivity, inadequate BMP prescription, major storm event, etc.):

(2) The degree and duration of effects on beneficial uses of water: